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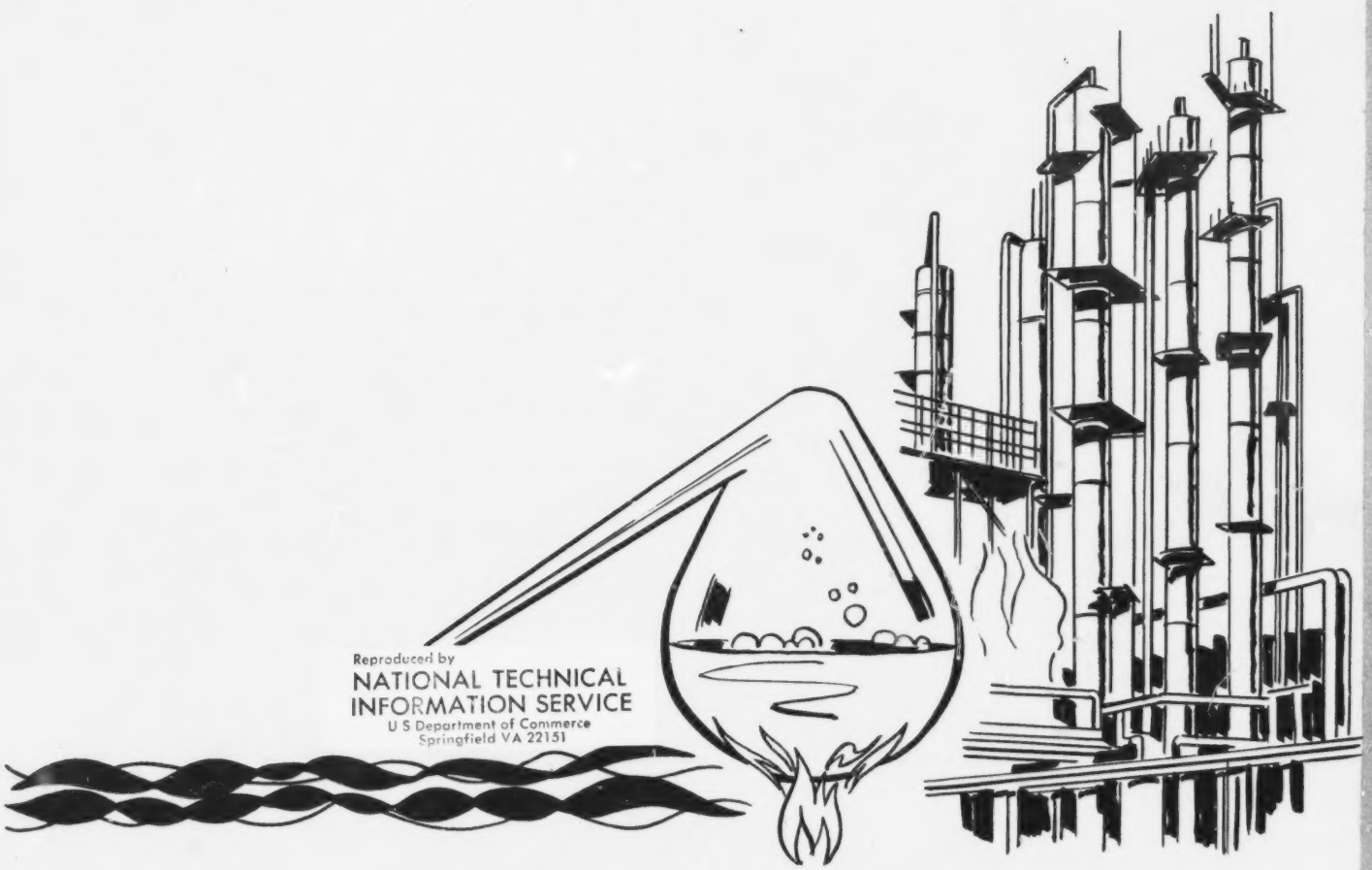
WASTEWATER TREATMENT FACILITIES FOR A POLYVINYL CHLORIDE PRODUCTION PLANT



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16. Abstract: B. F. Goodrich Chemical Company has completed construction and has begun operation of a new polyvinyl chloride (PVC) production plant that includes emulsion, suspension, and bulk polymerization processes. The wastewater treatment system for this plant was designed to meet the stringent discharge requirements of both the State of New Jersey and the Delaware River Basin Commission. The wastewater treatment system consists of a primary-secondary completed mixed activated sludge process including equalization, flocculation, clarification, mechanical aeration, nutrient addition, sludge thickening and centrifugation, and automatic process monitoring. Although the company operates several PVC production plants in the United States, none of these plants could be considered to be a duplicate of the proposed production plant. Therefore, it was necessary to simulate the anticipated production plant wastes by selective sampling of the laboratory and pilot plant studies and a complete and detailed description of the full-scale wastewater treatment system was constructed. Actual operating data of the system was included and supplemented by discussion of individual unit operations and unit process performance. Evaluation of a full-scale wastewater recycle and reuse system was included. (Galwardi-Texas)

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WASTEWATER TREATMENT FACILITIES FOR A POLYVINYL CHLORIDE PRODUCTION PLANT

by

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Cleveland, Ohio 44115

for the

OFFICE OF RESEARCH AND MONITORING
ENVIRONMENTAL PROTECTION AGENCY

Project No. 12020 DJI
June, 1971

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SECTION I

CONCLUSIONS

1. Waste equalization facilities were found to be a prerequisite to the treatment of this type waste. Variations in organic loading, hydraulic loading, and problems encountered with shock loadings in the pilot plant studies substantiated this need.

2. Latex solids definitely have an adverse effect on a completely mixed activated sludge system. The solids tend to cling to the biological floc causing stickiness and extreme reduction in organic removals. In addition, these solids should be removed in order to minimize the difficulty in keeping the aeration tank contents in suspension; in order to maximize oxygen transfer; and to reduce the quantity of biological inert solids in the aeration tank.

These conclusions were supported by the initial difficulty encountered in obtaining reproducible data from toxicity studies and by the difficulties encountered in the biological treatment studies.

3. The method most suitable for removal of this type of solids and for accomplishing primary treatment was determined to be chemical coagulation-flocculation and clarification. The use of coagulants and coagulant aids is recommended. The salt of ferric iron was found to be more effective as a coagulant as compared to alum. Calgon 227 and Nalco 670 were found to be effective coagulant aids. The dosage requirement for coagulants and coagulant aids was found to be approximately 150 milligrams per liter, and 1 milligram per liter, respectively.

Dissolved air flotation was investigated and found to be ineffective for this type of waste. The floc formed was extremely fragile.

4. The wastes from this type of production plant were found to be nontoxic to a biological treatment system. It was, however, determined necessary to provide waste equalization and primary solids removal prior to such a system.

5. Of the secondary treatment methods investigated, a completely mixed activated sludge system was found to be most applicable for this type of waste.

Organic loading rates achievable with this system for this particular waste were found to be in a range between those for a conventional activated sludge system and a high rate system treating domestic wastes. A loading rate of 0.70 pounds of 5 day biochemical oxygen demand removed per day per pound of volatile suspended solids under aeration was established. This compares with ranges for conventional and high rate systems of 0.1 to 0.5 and 1.25 to 4.5, respectively (11).

Energy oxygen requirements were determined to be 0.90 pounds of oxygen per pound of 5 day biochemical oxygen demand removed. This compares with 0.50 for conventional systems treating domestic wastes (12).

Alpha and Beta factors were established at 0.5 and 0.96, respectively. The Alpha factor established for this waste was lower than that commonly found for other types of wastes. This was attributed in part to the large amount of soaps and emulsifiers in the wastes. These values compare with Alpha and Beta factors of 0.8 and 0.9, respectively, for domestic wastes.

Sludge production was determined to be 0.68 pounds of volatile suspended solids per pound of 5 day biochemical oxygen demand removed. This compares favorably with values of 0.5 to 0.7 for conventional systems treating domestic wastes (11).

The aeration basin detention time was established at 6 hours. A mixed liquor volatile suspended solids level of 2500 milligrams per liter was determined optimum for practical design.

Aeration basin pH adjustment was provided in order to prevent the growth of large numbers of filamentous organisms and bulking sludge.

This type of waste was found deficient in nitrogen and phosphorous levels necessary to support biological life. Supplemental nutrients are essential.

6. Activated carbon treatment was determined to be impractical for this waste. Poor adsorption capacities were attributed to the presence of water soluble long-chain organic soaps contained in the wastes.

7. Laboratory data indicated the contact stabilization process was not practical for treatment of this waste. The time requirements for adsorption of the soluble organics was found to be approximately equal to the time required for complete degradation.

8. Suspended solids removal efficiency has averaged greater than 95 percent through the flocculator-clarifier system (primary treatment); 99 percent through the secondary system; and 98 percent through the complete treatment system.

9. During initial operations of the plant biochemical oxygen demand average removal efficiency has been in excess of 98 percent resulting in an average effluent concentration of 2.4 milligrams per liter.

10. Wastewater recycle has been investigated and appears feasible. Plans are underway for installation of a permanent wastewater recycle and reuse system.

SECTION II

INTRODUCTION

In 1966, B.F.Goodrich Chemical Company initiated plans to construct a polyvinyl chloride (PVC) manufacturing facility on the Delaware River in Salem County, New Jersey. This facility would employ emulsion, suspension, and bulk polymerization processes (1,2,3,4) and would generate waste waters containing monomers, polymers, organic and inorganic salts, organic acids, resin and rubber fine solids, dispersants, wetting agents, and catalyst.

The wastewater discharges from this manufacturing facility were subject to the requirements of the State of New Jersey Department of Health and the Delaware River Basin Commission. A minimum of secondary treatment and a 90 percent removal of biochemical oxygen demand was required.

In order to competently design an industrial wastewater treatment system to meet these established requirements, extensive laboratory and pilot plant investigations were performed at the Company's environmental control laboratory. These investigations were performed under the direction of graduate sanitary engineers from the Company and from Roy F. Weston & Associates.

Both primary and secondary treatment methods were investigated. Waste equalization; solids removal by chemical coagulation, dissolved air flotation, and clarification; activated carbon adsorption; contact stabilization; completely mixed activated sludge; and various other methods were considered and studied.

This report discusses the studies performed with a major emphasis placed on those processes found most applicable to the treatment of PVC wastes. A description of laboratory methods and pilot plant equipment is included. Typical data is presented and interpreted in terms of process design. Significant observations, specifically pertaining to the treatment of PVC wastes, are included along with a detailed and comprehensive process design summary. In addition, full-scale plant operation is discussed in relation to invidivual unit operations and unit processes. Problems encountered during initial start-up operations are presented including recommendations for system improvements. Actual operating data is included.

Lastly, wastewater recycle and reuse is included. The project was supported in part by the Office of Research and Monitoring, Environmental Protection Agency. Since completion of the wastewater treatment system, over 250 persons from 25 states and 3 foreign countries have toured the facilities.

SECTION III

DESIGN REQUIREMENTS

The waste water effluent from B.F.Goodrich Chemical Plant in Oldmans Township, New Jersey is subject to the Effluent Quality Requirements and Water Quality Objectives as established by the New Jersey State Department of Health and the Delaware River Basin Commission.

The New Jersey State Department of Health requires treatment "to a degree providing, as a minimum, ninety percent of reduction of biochemical oxygen demand at all times and such further reduction of biochemical oxygen demand as may be necessary to maintain the receiving waters, after reasonable effluent dispersion, as specified in the regulations entitled, "Regulations Concerning Classification of the Surface Wasters of the Delaware River Basin, Being Waters of the State of New Jersey, effective July 28, 1967". (5)

The Delaware River Basin Commission on April 26, 1967, adopted Section X of the Comprehensive Plan entitled "Water Quality Standards for the Delaware River Basin". Section 2-1.3, Effluent Quality Requirements, and Section 3-3.6, BOD Reduction of these requirements, are quoted below.

Section 2-1.3 Effluent Quality Requirements:

(1) Minimum Treatment. All wastes shall receive a minimum of secondary treatment, regardless of the stated stream quality objective.

(2) Disinfection. Wastes (exclusive of stormwater bypass) containing human excreta or disease producing organisms shall be effectively disinfected before being discharged into surface bodies of water.

(3) Public Safety. Effluents shall not create a menace to public health or safety at the point of discharge.

(4) Limits. Discharges shall not contain more than negligible amounts of debris, oil, scum or other floating materials, suspended matter which will settle to form sludge, toxic substances, or substances or organisms that produce color taste, odor of the water, or taint fish or shellfish flesh.

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Section 2-1.3 Effluent Quality Requirements: (continued)

(5) Allocation of Capacity. Where necessary to meet the stream quality objectives, the waste assimilative capacity of the receiving waters shall be allocated in accordance with the doctrine of equitable apportionment.

Section 3-3.6 BOD Reduction

The 85 percent minimum BOD reduction for secondary treatment will be determined by an average of samples taken over each period of thirty consecutive days of the year. From December 1 through March 31 a lesser percent reduction may be permitted by the Commission when it results from reduced plant efficiency caused by low atmospheric temperature, provided that the BOD reduction shall not be less than an average of 75 percent over any consecutive ten days.

B.F.Goodrich Chemical Company, therefore, established design objectives to meet or exceed these requirements. The waste treatment system was designed for 90 percent removal of ultimate biochemical oxygen demand at winter conditions, 13°C.

SECTION IV

DESIGN BASIS

B.F.Goodrich Chemical Company has several plants engaged in the production of polyvinyl chloride resins, similar to those to be produced at the Pedricktown, New Jersey plant. To estimate the design flows and effluent waste concentrations to be expected, data from these existing plants were inspected. Obviously, corrections were necessary to compensate for advanced process technology, improved housekeeping and water conservation practices, and differing production capacities.

In addition, complete theoretical process material balances were utilized for establishment of water usage and waste concentrations.

WATER USAGE

The waste water volume for the new plant was established at 800,000 gallons per day. This figure includes all process wastes, utility water, storm drainage from areas subject to accidental spills, storm drainage from critical tank farm diked areas, and a nominal expansion capacity. The new plant water usage per pound of product was established at approximately 20 percent less than the lowest usage figures for similar processes in existing plants.

WASTE LOAD

In many cases when a new production facility is being designed, synthetic wastes or process pilot plant wastes must be utilized for study. Fortunately in this particular case, many of the processes scheduled for the new plant were in production at an existing Goodrich plant. Thus for design purposes, waste water samples were taken from these existing processes and composited in proper proportion for the new plant production capacities.

The analyses of all samples were in accordance with "Standard Methods for the Examination of Water & Waste Water", 12th Edition, published by the American Public Health Association. Dissolved oxygen determinations were made with a YSI dissolved oxygen analyzer. Total carbon and total organic carbon determinations were made with a Beckman carbonaceous analyzer.

The analyses of these composited waste samples are shown in Table 1. With the exception of COD, these data were averaged and utilized for design. Necessary corrections were applied to compensate for factors previously discussed. A significant variation in organic and solids loading is apparent, thus indicating a need for waste equalization prior to any treatment process.

TABLE 1

RAW PROCESS WASTE CHARACTERISTICS*

Date	COD mg/l	TC mg/l	TS mg/l	VTS mg/l	SS mg/l	VSS mg/l	Turbidity JTU
3/29/68	1600	460	980	666	436	376	
3/30/68	1372	545	1728	1040	992	974	245
3/31/68	2660	590	1267	880			1760
4/10/68	7440	2600	4420	3816	2888	2856	8500
4/11/68	1068	380	1068	483	528	516	350
4/16/68	1960	800					168
4/17/68	3064	848					1070
4/18/68	3885	860	2363	447	456	412	1680
4/19/68	1546	460	1683	1148	678	632	190
4/22/68	6547	710					3200
4/23/68	4464	1410	1347	1079	348	340	2500
4/24/68	4464	1310	2098	1468	1902	1866	3800
4/25/68	2381	705	1359	1032	560	536	2140
4/26/68	2142	1000	2486	1712	1628	1584	2400
4/30/68	1904	390	1936	1249	1180	1112	
5/01/68	5356	1840	4060	3395	2688	2620	
5/02/68	4256	1520					
5/03/68	4365	1280	3290	3044	1392	1344	
5/06/68	6994	790	2884	1314	976	952	
5/07/68	1760	270	2808	1431	808	784	
Average		938	2230	1514	1164	1125	2160

*Necessary corrections have not been applied to this data.

COD = Chemical Oxygen Demand
TC = Total Carbon
TS = Total Solids
VTS = Volatile Total Solids
SS = Suspended Solids
VSS = Volatile Suspended Solids

Design parameters for organic loading were handled in a different manner. It was found that consistent and reproducible BOD_5 (5 day biochemical oxygen demand) results could not be achieved until the raw process wastes had been chemically clarified. Table 2 shows BOD_5 and COD data on chemically clarified process wastes. These data were ranked arithmetically and statistically analyzed. Design values for BOD_5 and COD were then selected, such that the probability of exceeding these values was less than 10 percent.

TABLE 2

CHEMICALLY CLARIFIED PROCESS WASTE
ORGANIC LOADING
RANKED DATA

BOD	N	$\frac{N}{n+1}$ 100	COD
356	1	3.3	820
410	2	6.7	832
427	3	10.0	843
482	4	13.3	920
490	5	16.7	940
493	6	20.0	964
543	7	23.4	976
548	8	26.7	1009
567	9	30.0	1016
583	10	33.4	1091
615	11	36.7	1115
629	12	40.0	1136
647	13	43.4	1178
658	14	46.7	1190
666	15	50.0	1192
690	16	53.4	1220
714	17	56.6	1270
744	18	60.0	1280
746	19	63.4	1309
752	20	66.6	1320
753	21	70.0	1360
767	22	73.5	1440
802	23	76.7	1449
808	24	80.0	1449
873	25	83.4	1473
901	26	86.7	1557
1036	27	90.0	1599
1254	28	93.4	1768
1470	29	96.7	3030

In summary, the following data were developed characteristic of the raw process wastes. The BOD_5 and COD results represent chemically clarified process wastes.

Waste Volume	=	800,000 GPD
BOD_5	=	720 mg/1
COD	=	1,285 mg/1
TS (Total Solids)	=	2,000 mg/1
SS (Suspended Solids)	=	1,000 mg/1
VSS (Volatile Suspended Solids)	=	950 mg/1

In addition, variations in both hydraulic and organic loading were observed. Moreover, it was found that chemical clarification of the wastes was necessary in order to achieve reproducible BOD_5 data. This also further substantiates the need for waste equalization.

SECTION V

PRIMARY TREATMENT METHODS

The waste streams to be treated originate predominantly from emulsion, suspension, and bulk polymerization processes. In general the waste can be characterized as milky white in color and containing various amounts of monomers, polymers, organic and inorganic salts, organic acids, resin and rubber fine solids, dispersants, wetting agents, catalysts, and trace amounts of heavy metals. In addition, the waste may be further characterized by the data in Table 1, Section IV.

This section discusses the laboratory investigations performed in order to develop a primary treatment method applicable to this waste. The methods investigated consisted of chemical coagulation, dissolved air flotation, and settling. The procedures and apparatus used will be discussed; data will be presented; and conclusions will be drawn.

CHEMICAL COAGULATION

In general, the solids in the wastewater can be described as 80 percent settleable, 15 percent colloidal, and 5 percent floating. To remove colloidal solids, to settle floating solids, or to raise settleable solids, a coagulant is needed. A coagulant will stabilize the colloidal materials and form floc materials, thus enhancing sedimentation or flotation, depending on the particular application.

A coagulant aid may also be used with a coagulant in order to promote the formation of larger floc particles, thus enhancing solids removal.

Several coagulants and coagulant aids were used to determine the right combination for this particular waste effluent. The coagulants tested were alum, ferri-floc, and ferric chloride. The coagulant aids used were anionic, cationic, and non-ionic.

The Phipps-Bird jar test apparatus was used when performing these studies. The equipment consists of six mixers with variable speeds (0 to 100 rpm) and six one-liter beakers. Each waste sample tested was one liter in size.

In all cases, each sample was mixed at 100 rpm and the chemicals were added. After two minutes of the flash mix, the mixer was adjusted to 50 rpm for five minutes. The final 10 minutes were conducted at 10 rpm in order to promote floc growth. It was important to mix the coagulant first at 100 rpm and then add the coagulant aid. Reversing the order would not produce a satisfactory floc particle.

When testing for the type of coagulant, each coagulant was tested alone; coagulant aids were not used at this point. The results of the coagulation tests indicated the salt of the ferric ion worked best. The alum worked fairly well. Good results with alum were achieved only in a narrow pH range close to 8. The Fe^{+++} worked well over a wide pH range (4.0 to 10.0) and because of this was considered best for the results needed for this system. The optimum dosage for the Fe^{+++} was 150 mg/l as $FeCl_3$.

The coagulants aids were tested using the Fe^{+++} at an optimum dosage, as indicated by the results of previous tests. The results indicated that a slightly cationic to non-ionic polyelectrolyte was the best for the purposes of the study. The chemicals that worked well were Calgon 227[6] and Nalco 670.[7] The optimum dosage of polyelectrolyte was 1 mg/l.

The data in Table 3 shows typical results obtained using a composite waste sample similar to that which was expected to exist at the Pedricktown plant. Note that the coagulant dosage was 150mg/l, and the coagulant aid dosage was 1mg/l. Turbidity was used as a parameter for solids removal efficiency. In all cases, a significant amount of turbidity was removed. COD was also used as a measure of efficiency; however, the COD is only a function of the removal of solids which have soluble organics attached to them.

TABLE 3

COAGULATION DATA

	Before Coagulation			After Coagulation			
Sample	Turbidity	COD	pH	pH	COD	Turbidity (Clarified)	*Suspended Solids
1.	1800 JTU	778 mg/1	9.3	5.7	778 mg/1	10 JTU	1114 mg/1
2.	860 JTU	1532 mg/1	11.0	9.8	1109 mg/1	44 JTU	779 mg/1
3.	400 JTU	1863 mg/1	11.0	6.7	1552 mg/1	55 JTU	671 mg/1
4.	950 JTU	2621 mg/1	12.4	5.8	1935 mg/1	24 JTU	427 mg/1

NOTE: 1. 150 mg/1 $FeCl_3$ coagulant dosage and 1 mg/1 coagulant aid dosage was used for all samples.

* 2. The final suspended solids data is that of the total sludge before settling. These figures were obtained for sludge treatment design purposes.

In conclusion, it was determined that coagulation is an effective method of solids agglomeration from the waste under investigation. The salt of ferric ion was found to work best at dosages of approximately 150 mg/l. In addition, Calgon 227 and Nalco 670 coagulant aids were found to enhance solids removal. The order of addition of the coagulant and coagulant aid was found to be of importance. The coagulant must be mixed first.

Once a suitable dosage of coagulant and coagulant aid was determined, the next step was to determine the best method of solids removal. The methods of dissolved-air flotation and settling were investigated. These methods were evaluated by the volume rate of which suspended solids were removed.

DISSOLVED-AIR FLOTATION

To remove waste materials, using the principle of dissolved-air flotation, air is dissolved in water under pressure, injected into the waste sample, and released. The result is thousands of micro-bubbles rising to the surface. These small bubbles cling to the floc particles and suspended matter carrying them to the surface.

The equipment used consisted of a one-gallon pressurizing cylinder, a one-liter graduated cylinder, and the Phipps-Bird mixing apparatus described previously. The procedure followed for coagulating the waste was the same as that described in the previous section. After a sample had been coagulated, a portion was put into the graduated cylinder. Before the floc could settle, air-saturated water under approximately 40 PSIG pressure was injected into the base of the cylinder. The micro-bubbles released carried the materials to the surface.

Dissolved-air flotation proved very ineffective for this particular waste. The floc formed was extremely fragile and acceptable solids removal could not be accomplished.

SETTLING

The equipment used for the settling consisted of an eight foot plexiglass column with sample ports at each foot of depth as shown in Figure 1. The coagulant and coagulant aid dosage was known from previous jar tests. The dosage for the column was based on a five-gallon sample volume.

The procedure consisted of thoroughly mixing the coagulant and coagulant aid into the five-gallon sample. This sample was then pumped into the plexiglass column. A multi-blade, 6 RPM agitator inside the column was used to flocculate the waste for a period of 15 to 20 minutes. Following flocculation, samples were taken from the one and six foot depth sample ports and were considered zero time samples. The average

of the two zero time samples was used as the initial suspended solids for the waste. At set time intervals, additional samples were taken from one, two, four, and six foot sample ports. All samples were analyzed for suspended solids.

The data shown in Table 4 indicates the suspended solids at various time intervals and depths in the column for both coagulated and uncoagulated wastes. The depths indicated are measured from the top of the column down. The results clearly indicate the need for chemical coagulation. As shown, the maximum suspended solids removed at a point of one foot depth in the column was 48 percent of the total for uncoagulated wastes. For coagulated wastes, approximately 95 percent of the suspended solids were removed after 30 to 60 minutes of settling.

All data completed on settling tests gave results of 95 percent suspended solids removal. From this data a primary clarifier overflow rate was established at 1000 GPD/ft^2, and the detention time at 2.8 hours. Appropriate scale-up factors were used to compensate for the ideal settling conditions of the study.

FIGURE 1

SETTLING COLUMN

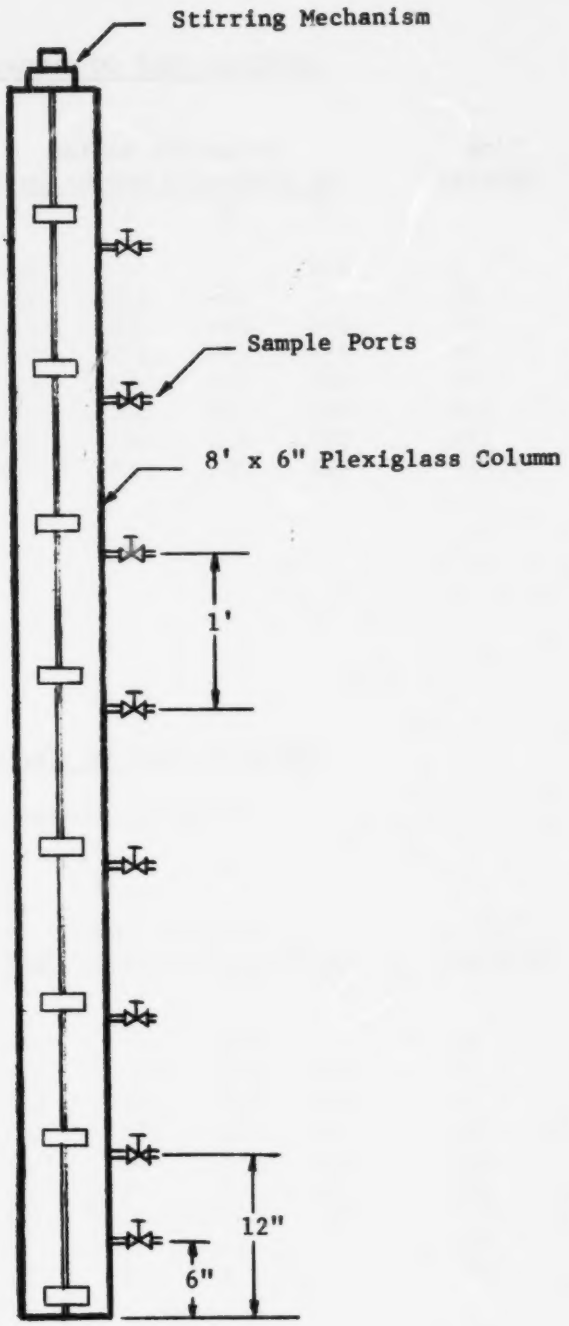


TABLE 4

SETTLING TEST ON UNCOAGULATED EFFLUENT

Time Minutes	Suspended Solids at Indicated Depths mg/l				% Suspended Solids Removed at Indicated Depths			
	1'	2'	4'	6'	1'	2'	4'	6'
0	496			496				
10	390	476	320	220	21	4	35	66
20	260	320	320	270	48	35	35	45
30	270	330	376	380	45	33	25	23
60	480	390	440	360	3	21	11	27
120	260	390	360	410	48	21	27	17
180	280	340	480	380	43	31	3	23
1,080	280	290	500	320	43	41	xx	35

SETTLING TEST ON COAGULATED EFFLUENT

Coagulant Dosage = 150 mg/l

Time Minutes	Suspended Solids at Indicated Depths mg/l				% Suspended Solids Removed at Indicated Depths			
	1'	2'	4'	6'	1'	2'	4'	6'
0		494		799				
1	330	402	537	624	49	38	17	3
5	199	209	256	461	69	68	60	29
10	78	102	111	163	88	84	83	75
20	46	55	62	57	93	91.5	90.5	91
30	35	41	51	36	95	94	92	96
60	26	34	34	39	96	95	95	94
90		14	39	37		98	94	94
130		8	21	31		99	97	95

SECTION VI

TOXICITY STUDIES

During the preliminary waste characterization studies, extreme difficulty was encountered in developing consistent and reproducible BOD data. This factor indicated the possibility of elements in the wastes which were toxic to microorganisms commonly utilized in wastewater treatment operations. Therefore, before detailed biological treatment studies were begun, toxicity studies were conducted. Waste streams were investigated on both an individual and composite basis.

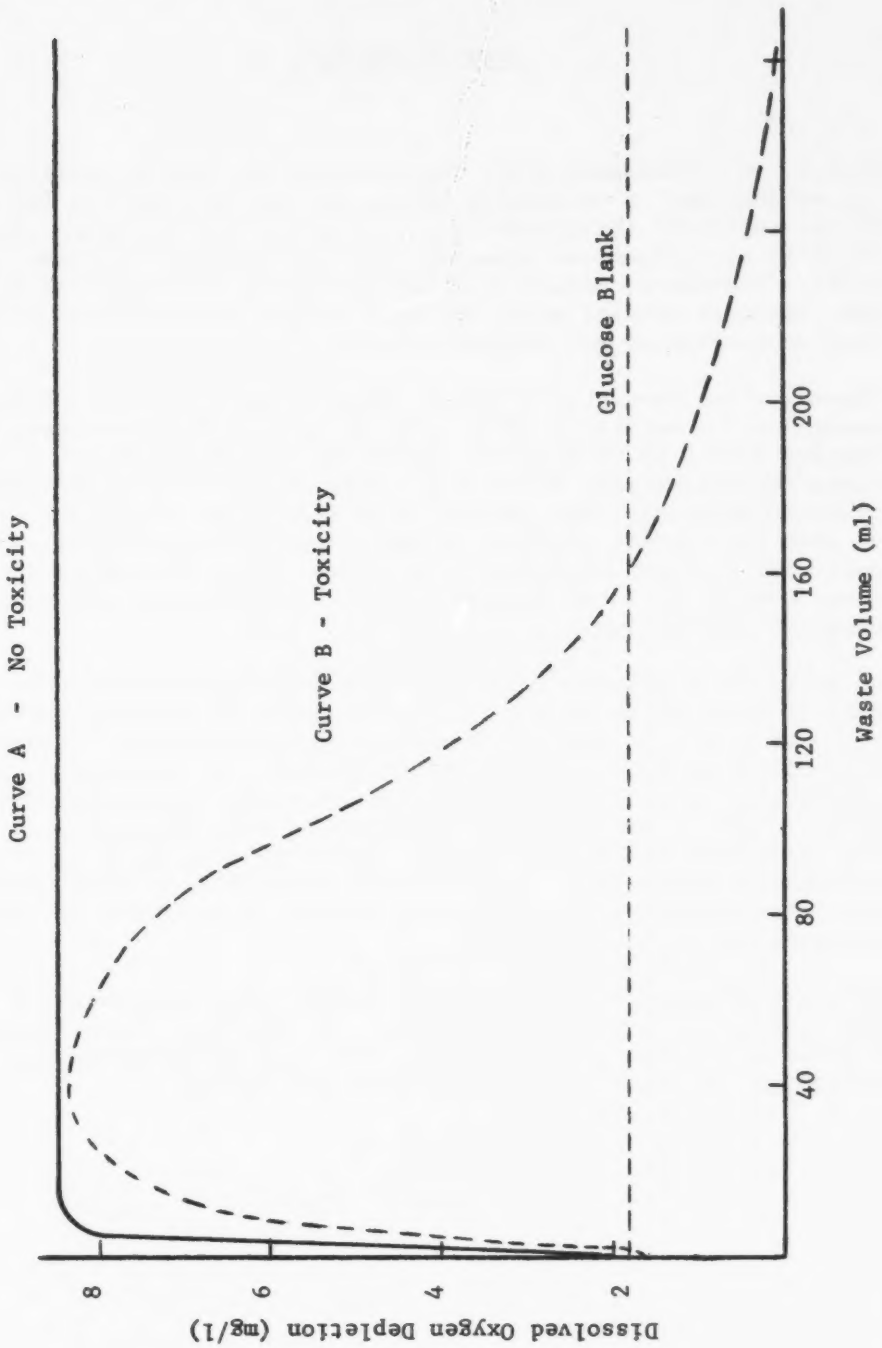
These studies consisted of batch tests using standard BOD determinations. A series of BOD's were prepared with waste concentrations ranging from 0 to 98 percent. Prior to setting up the BOD determinations the wastes were chemically clarified. To insure that biodegradable materials were present, 0.12 milligrams of glucose was added to each BOD bottle. Acclimated seed, nutrients, and dilution water were added before incubation. Dissolved oxygen (DO) measurements were taken before and after incubation. A YSI DO analyzer was used for oxygen determinations.

A plot of DO concentration versus waste concentration will indicate if toxicity is present. If no toxicity is present, the DO concentration will decrease as the waste concentration increases. This will continue until all DO is depleted. If toxicity is present the DO will deplete to a point where the waste concentration becomes toxic. Beyond this point the DO depletion will decrease with increasing waste concentration. Figure 2 shows the results of toxicity studies on composite wastes. Curve B illustrates a toxic waste. It was later found that this toxicity was due to an excess of hexavalent chromium from a process spill.

It was concluded that the combined wastes under investigation would not be toxic to a biological system. In addition, these studies further substantiated the need for providing equalization and spillage isolation facilities prior to a biological system.

FIGURE 2

TOXICITY CURVES



SECTION VII

SECONDARY TREATMENT METHODS

In order to achieve the treatment levels as outlined in Section III, it was necessary to provide secondary treatment. The methods of secondary treatment considered consisted of activated carbon and various biological systems.

Activated carbon adsorption isotherm tests were conducted on the chemically clarified wastes. These tests indicated that the adsorption capacity of activated carbon was relatively poor for these particular wastes. This poor adsorption capacity was attributed to water soluble long-chain organic soaps contained in the wastes. It was thus concluded that activated carbon treatment would not be a practical or economical method of achieving secondary treatment. Therefore, no further carbon studies were conducted.

The biological systems considered consisted of an aerated lagoon, a completely mixed activated sludge system, and contact stabilization.

The aerated lagoon was eliminated due to excessive area requirements and the degree of treatment attainable from this type process.

Laboratory data indicated that the contact stabilization process was not practical. The time requirements for adsorption of the soluble organics was found to be approximately equal to the time required for complete degradation.

Past experience in the waste treatment field has shown the completely mixed activated sludge process to be highly efficient and more capable of withstanding shock loading. For this reason it was decided to further investigate the feasibility of utilizing this system.

At this point a completely mixed activated sludge pilot plant process was designed and operated in order to develop design parameters for a treatment system.

The consulting firm of Roy F. Weston & Associates was contracted to provide assistance in these studies. Design data was developed from both the continuous pilot process and from batch tube run studies which utilized the sludge produced in the continuous pilot process. The tube runs were conducted in accordance with procedures developed by the consultant (8, 9, 10) as described in the referenced report. No further description is included in this report.

The data developed from the continuous and batch studies compared closely with the exception of oxygen requirements. With this exception, the data developed from the continuous pilot plant was used for design purposes since the continuous system represented the waste stream over a longer period of time.

The following paragraphs describe the equipment and the methods of operation used in the continuous pilot plant studies. Data on the final pilot plant study will be presented and discussed. Calculations leading to the selection of process design conditions will be presented and important observations will be discussed.

CONTINUOUS PILOT PLANT

In these studies a completely mixed activated sludge system was simulated by providing sludge recycle and mixing of the aeration tank contents. The equipment used is shown in Figure 3 and consisted of a 55-gallon equalization and feed tank, a 6-gallon aeration tank, a 5-gallon conical clarifier, aeration diffuser, and appropriate pumps.

The biological system was started by placing a mixture of activated sludge from a nearby sewage treatment plant in the aeration tank. Chemically clarified process waste was placed in the feed tank. Essential nutrients were added. The waste feed pumps were started at a low initial feed rate in order to allow acclimatization of the organisms. The process was operated under various conditions of feed rate, detention time, sludge recycle rate, and at various mixed liquid volatile suspended solids levels (MLVSS). Some of the data developed is shown in Table 5 The symbols and terms used are discribed below.

Q_1 = Feed rate of the chemically clarified process wastes, ml/min.

Q_2 = Sludge recycle rate, ml/min.

T = System operating temperature, °C.

L_o = BOD_5 of the chemically clarified process wastes, mg/l.

FIGURE 3

BIOLOGICAL REACTOR

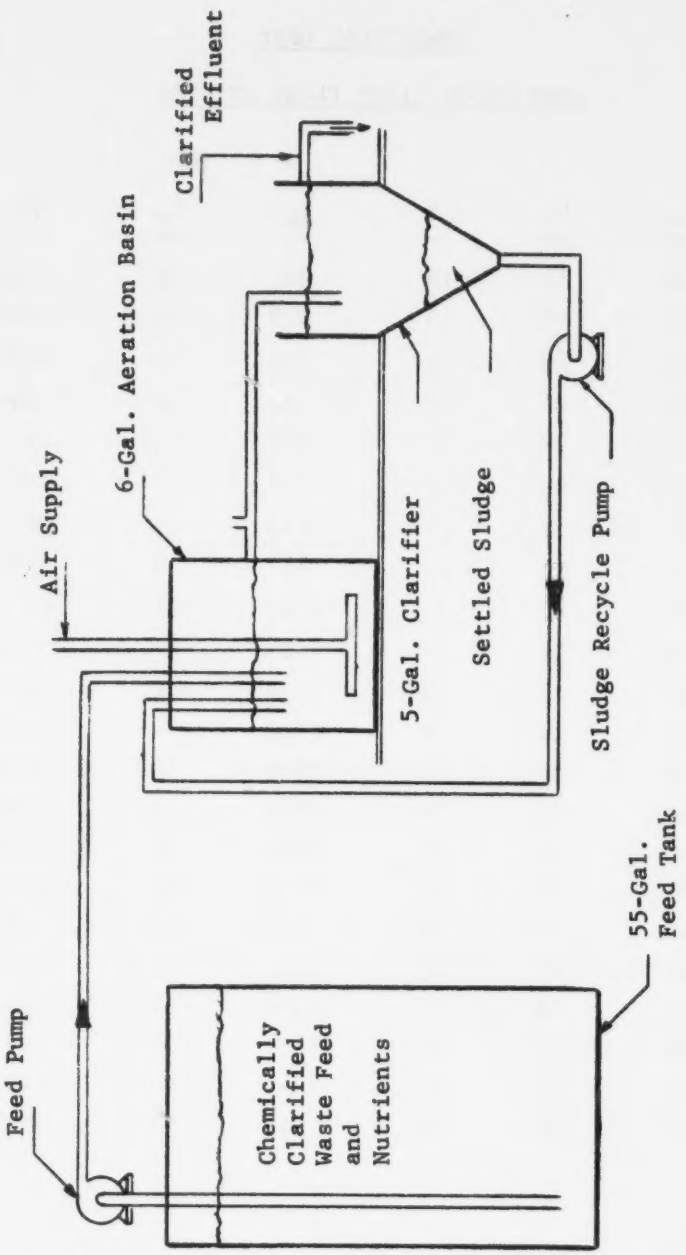


TABLE 5

ANALYTICAL DATA

CONTINUOUS PILOT PLANT STUDIES

Date	Q_1	Q_2	T	L_o	L_e	S_i	T_e
4/5	10	10	16	802	26	1780	1133
4/6	17	17	23	873	26	1220	670
4/10	24	24	21	901	24	2160	473
4/11	24	24	20	752	24	1980	473
4/15	30	30	20	636	14	2130	378
4/16	30	30	19	629	18	1900	378
4/19	47	47	22	1470	15	3020	242
4/20	50	50	22	753	13	2950	227
4/21	50	50	25	2120	25	4600	227
4/22	58	58	23	1328	57	3290	186
4/23	50	50	20	1236	25	3190	227
4/24	48	36	20	2100	16	3700	270
4/25	48	36	17	2000	30	4670	270
4/27	66	67	20	1096	40	4030	186
4/28	48	50	22	1019	25	3180	220
4/29	55	59	24	1515	50	3500	204
5/1	48	51	20	1065	36	3860	238
5/2	64	70	17	1113	44.3	4190	179
5/3	66	72	22	1348	55.0	2940	173
5/4	66	72	21	1158	50.0	4290	173
5/5	66	72	20	1244	44.0	4630	173
5/6	65	68	18	928	23.0	3820	175

L_e = Equilibrium BOD_5 which is equivalent to the effluent BOD_5, considering the system is operating continuously at equilibrium.

S_i = MLVSS in the aeration tank, mg/l.

t_e = Detention time in the aeration tank, min.

From the data in Table 5 and the system geometry, the relationship of the BOD_5 removal rate coefficient (r) to the load rate Li/Si can be developed as shown in Figure 4. The BOD_5 removal rate coefficient is a measure of the rate of BOD_5 removal from the aeration tank under equilibrium conditions; that is,

$$r = \frac{L_i - L_e}{t_e L_e} \quad \text{min.}^{-1}$$

where L_i = BOD_5 of the aeration tank influent, mg/l

$$= \frac{Q_1 L_o + Q_2 L_e}{Q_1 + Q_2}$$

The load ratio = L_i/S_i, mg/l BOD_5/mg/l MLVSS, and may be defined as a measure of the food to microorganism ratio in the aeration tank.

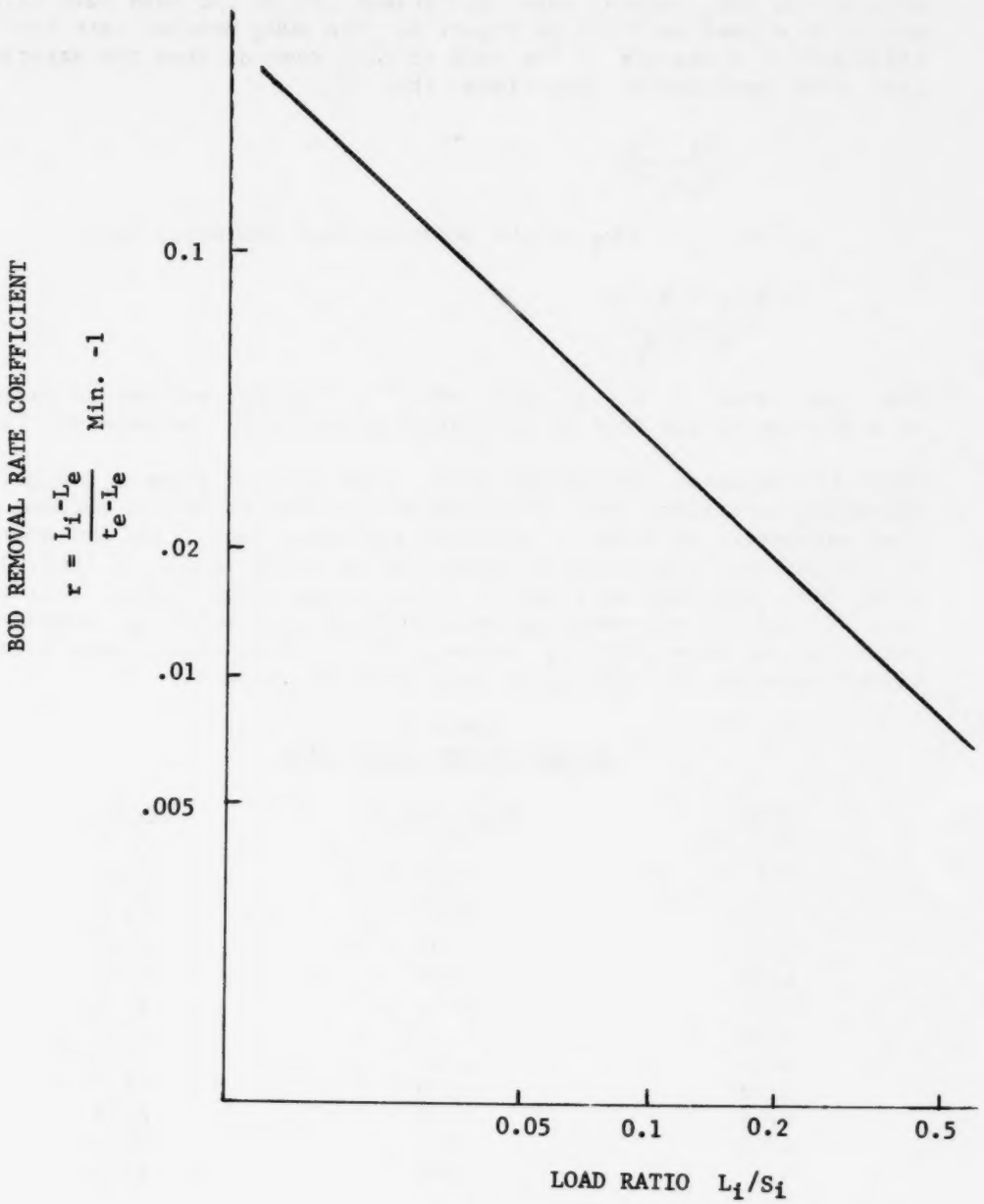
Once this relation was established, then various process design and operating conditions were investigated in order to define optimum design parameters in terms of physical equipment capacities and operational flexibility. Calculations were made at MLVSS levels of 1500, 2000, 3000, 3500, and 5000 mg/l and at three sludge volume index (SVI) levels; 100, 150 and 200 representing conditions of good settling, average settling, and poor settling respectively. These values were established based on the laboratory data shown in Table 6.

Table 6.
SLUDGE VOLUME INDEX DATA

DATE	MLSS (mg/l)	SVI
4/7	1890	97.8
4/9	2090	83.7
4/17	2900	62.1
4/18	3060	68.6
4/23	3490	68.8
4/24	3980	61.6
4/25	4670	63.2
4/26	5320	59.2
4/27	4380	57.1
4/28	3570	58.8
4/29	3920	63.8
4/30	5440	53.3
5/1	4640	62.5

FIGURE 4

BOD REMOVAL RATE VS LOAD RATIO



Note that the SVI shown in the Sludge Volume Index Data on the preceding page, was less than 100 for all MLVSS levels, indicating good sludge settling characteristics.

For the calculations, a design flow of 0.8 MGD was used at a BOD_5 concentration of 720 mg/1. All calculations were based on a 90 percent BOD removal at winter conditions (13° C.).

The following equations were used for calculating the data shown in Table 7.

(1) MLVSS (mg/1) = 90% MLSS $\qquad$ $MLSS = \frac{MLVSS}{90\%}$

(2) Recycle SS (mg/1) = $\frac{1 \times 10^6}{SVI}$

(3) Percent Recycle of Forward Flow = $\frac{MLSS}{\text{Recycle SS} - MLSS}$ 100

(4) Basin Volume = (Design Flow Rate)(1 + Percent Recycle) t_e

where t_e = detention time

$$= \frac{Li - Le}{r_{13°C}\, Le}$$

where r is determined from Figure 4 and corrected to 13°C.

Analysis of the calculated data in Table 7 show a considerable variation in recycle rates, aeration basin volumes, and detention time for the MLVSS levels investigated. Variation at the individual MLVSS levels for the selected SVI's were less extreme. It was desired to select a MLVSS concentration sufficiently high in order to minimize basin volume while at the same time holding the sludge recycle rates within reasonable operational ranges. For these reasons, a MLVSS level of 2500 mg/1 and an SVI of 150 was selected for design parameters. Up to this 2500 mg/1 level, the aeration basin volume requirements remained essentially constant for all SVI levels up to 200. In addition, the corresponding sludge recycle rate requirements are manageable for the SVI levels up to 200.

As previously indicated, the oxygen requirements were developed from the tube run studies. It was found that 0.9 pounds of energy oxygen were required per pound of BOD_5 removed (equivalent to 4100 pounds oxygen per day). In addition, the endogenous oxygen requirement for the design VSS level was found to be 875 pounds per day. In combination, the total oxygen requirement amounted to 207 pounds per day (equivalent to 70 mg/1/hr.).

TABLE 7

Activated Sludge System Design Data

MLVSS (mg/1)	1500			2500			3500		
SVI	100	150	200	100	150	200	100	150	200
Recycle (%)	20	33.4	50	38.5	71.5	125	63.6	141	350
Recycle (GPM)	112	186	278	214	398	696	354	785	1950
Process Eff. (%)	88.1	87	85.9	86.6	84	80	84.6	78.9	66.7
L_i, (mg/1)	611	556	505	540	450	360	468	341	216
Basin Volume Gallons X 10^{-4}	42.8	43.9	43.2	34.8	35.4	32.0	30.1	23.5	18.0
Detention Time Min. at "r" 13°C.	640	590	500	450	370	255	330	175	72

Excess sludge production values also were determined from the tube run studies. It was found that 0.68 pounds VSS were produced per pound of BOD_5 removed; 51 pounds of VSS were destroyed per 1000 pounds VSS under aeration; and that 50 mg/l SS would be lost in the secondary clarifier effluent.

In summary, the design parameters developed from the biological studies, which were later used for design purposes, consisted of:

MLVSS Concentration	=	2500 mg/l
SVI	=	150
Sludge Recycle Rates	=	0-125%, normal = 71.5%
Aeration Basin Volume	=	354,000 gallons
Detention Time	=	370 minutes
Oxygen Requirements	=	70 mg/l/hr.
Sludge Production	=	0.68# VSS/#BOD_5 removed

In addition to these specific parameters, several important observations were made relative to the biological treatment of PVC wastes. The significance of these observations was incorporated into the system design. Such observations are discussed below.

1. Solids removal prior to biological treatment -

   It was found that latex solids definitely have an adverse effect on a completely mixed activated sludge system. These solids tend to cling to the biological floc causing stickiness and extreme reductions in organic removal. In addition, these solids should be removed in order to minimize the difficulty in keeping the aeration tank contents in suspension; in order to maximize oxygen transfer; and in order to reduce the quantity of biologically inert solids in the aeration tank.

2. pH adjustment -

   Provisions should be made for caustic addition in order to prevent the pH from dropping significantly below 7.0. On two separate occasions the pH in the aeration tank dropped to approximately 5.0 for short periods of time. This resulted in the presence of large numbers of filamentous organisms and a bulking sludge.

3. Supplemental nutrients -

   This type of waste was found to be deficient in nitrogen and phosphorous levels necessary to support biological life. Supplemental nutrients are essential.

4. Equalization -

The waste from this type of production process was found to be variable in hydraulic and organic loading. A one day waste equalization time is recommended in order to prevent "shocking" of the biological treatment process.

SECTION VIII

OXYGEN TRANSFER STUDIES

Oxygen transfer studies were conducted to determine the transfer characteristics of the waste. In order to size aeration equipment it was necessary to know alpha (α) and beta (β). Alpha is the ratio of the transfer coefficient in waste water to the transfer coefficient in tapwater. Beta is the ratio of oxygen saturation values.

The equipment used is shown in Figure 5. Mixed liquor was placed in the basin and the surface aerator started. Once the test had started none of the equipment could be moved. Changing the position of the aerator or basin would change the overall oxygen transfer coefficient ($K_L a$) that was obtained, and therefore give an invalid value for α.

Waste water was fed into the basin for the purpose of determining an equilibrium dissolved oxygen value. When the feed is started the dissolved oxygen will begin to drop. When the dissolved oxygen stabilizes, this value is recorded and the oxygen uptake rate is measured by recording DO versus time.

The basin was then emptied, cleaned, and refilled with tapwater without moving the basin. The dissolved oxygen was then removed using sodium sulfite. Cobaltous chloride was used as the catalyst. The surface aerator was then started at the same speed as was used on the mixed liquor. The values of DO versus time were recorded as oxygen was transferred to the water.

The saturation values (C_s) were obtained by aerating supernate and tapwater until saturation was obtained.

The rate of diffusion of oxygen from the gas to the liquid depends on the temperature, the driving force (concentration gradient), the area across which diffusion takes place, and the characteristics of the waste. The process is defined by Fick's law:

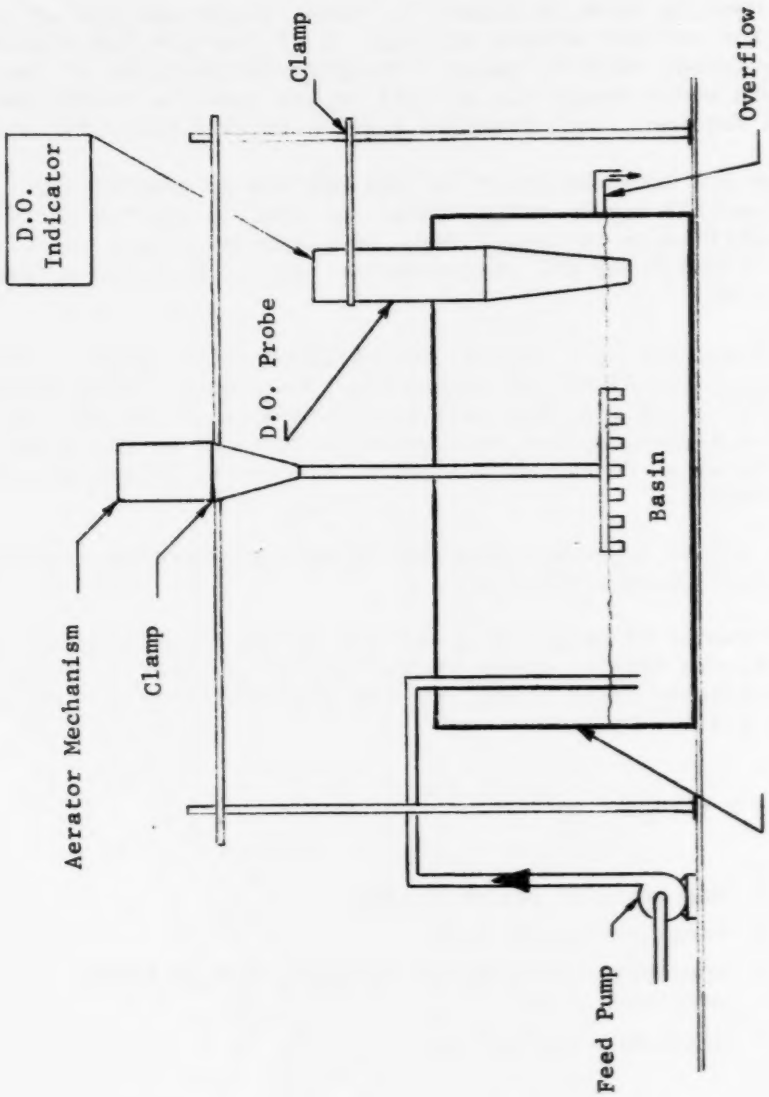
$$N = (D_L A) \frac{dc}{dy} \qquad (1)$$

where:

- N = mas transfer per unit time
- A = cross sectional area
- dc/dy = concentration gradient perpendicular to cross-sectional area
- D_L = diffusion coefficient

FIGURE 5

OXYGEN TRANSFER MEASUREMENT APPARATUS



Assuming that equilibrium exists at the interface, Lewis and Whitman developed the two film concept. This concept considers infinitely small stagnant films at the gas and liquid interface through which the gas is transferred. Fick's law can be rewritten as:

$$N = K_L A\ (C_s - C) = KgA\ (pg - p) \qquad (2)$$

where:

K_L = liquid film coefficient

Kg = gas film coefficient

C = dissolved oxygen concentration

p = partial pressure of oxygen

For oxygen and other slightly soluble gases, the liquid film will control. Since $N = (dc/dt)V$ equation (1) can be re-expressed as:

$$dc/dt = K_L(A/V)\ (C_s - C) \qquad (3)$$

For convenience, $K_L(A/V)$ is usually expressed K_La which is the overall transfer coefficient.

$$dc/dt = K_La\ (C_s - C) \qquad (3\text{-A})$$

In an activated sludge system there is a simultaneous oxygen uptake while the oxygen is being transferred. Equation (3) becomes:

$$dc/dt = K_La\ (C_s - C) - r \qquad (4)$$

where:

r = biological oxygen uptake rate

If, as in the laboratory test, the system is in steady state:

$$dc/dt = 0$$

$$\text{and } K_La = r/C - C \qquad (5)$$

To find K_La on tap water, a non-steady method must be used. Rearranging equation (3-A) and integrating both sides gives:

$$\frac{dc}{C_s - C} = (K_La)\ dt \qquad (6)$$

$$\int_{C1}^{C2} \frac{dc}{C_s - C} = \int_{t_1}^{t_2} (K_La)\ dt \qquad (7)$$

$$\Delta \ln\ (C_s - C) = (K_La)\ \Delta t \qquad (8)$$

$$K_La = \frac{\Delta \ln\ (C_s - C)}{\Delta t} \qquad (9)$$

From equation (9) it can be seen that $K_L a$ would be the slope of a plot of ln $(C_s - C)$ versus time.

Knowing the two $K_L a$'s, the value of

$$\alpha = \frac{K_L a \text{ Waste Water}}{K_L a \text{ Tap Water}}$$ can be determined.

β is equal to the saturation concentration in wastewater divided by saturation concentration in tap water.

The value of α obtained was considerably lower than that normally found in domestic waste. This was due to waste characteristics. The presence of surface active agents and other organics will have a profound effect on $K_L a$. Molecules of surface active materials will orient themselves on the interfacial surface and create a barrier to diffusion. The excess surface concentration is related to the change in surface tension, as defined by the Gibbs equation, such that small concentrations of surface active material will depress $K_L a$, while large concentrations will exert no further effect. The absolute effect of surfactants on $K_L a$ will also depend on the nature of the aeration surface. Less effect would be exerted at a highly turbulent liquid surface, since the short life of any interface would restrict the formation of an adsorbed film. Conversely, a greater effect would be exerted at a bubble surface because of the relatively long life of the bubble as it rises through an aeration tank. In some cases, the reverse effect may be noticed. The decrease in surface tension will decrease the size of bubbles and this will increase the area volume ratio (A/V). If the increase in A/V exceeds the decrease in K_L, then the $K_L a$ will increase over that in water. These cases, however, are unusual.

The actual data and calculations of the three tests are shown in Tables 8, 9, and 10, and Figure 6. The average α value of the three runs is 0.434. The average of β is 0.963. Since the consultant indicated that a higher α value was usually observed in the field than in laboratory studies, a value of $\alpha = .5$ was used for design. With values of α and β and the oxygen requirement developed in Section VII, and aerator manufacturer can size necessary equipment.

TABLE 8

OXYGEN TRANSFER STUDIES
TEST #1

A. Determination of $K_L a$ of tap water
Temperature 18.2° C. 0_2 Saturation 9.20

Time (min.)	D.O. (mg/1)	C_s-C
0	.28	8.92
1	3.10	6.10
2	5.38	3.82
3	6.82	2.38
4	7.70	1.50
5	8.32	.88
6	8.69	.51
7	8.90	.30

$K_L a = 2.303 \times .203 = .474 \text{ min.}^{-1}$

B. Determination of $K_L a$ of waste water

Temperature - 18.2° C.

Dissolved Solids 1,067 mg/1

Saturated Oxygen concentration (corrected for dissolved solid)

Supernate 8.74 mg/1

Oxygen transfer

a. Equilibrium oxygen concentration 2.90 mg/1
b. Biological uptake rate 67.9 mg/1/hr.

Transfer coefficient

$K_L a = r/C_s - C_e$

$$K_L a = \frac{67.9}{8.74 - 2.90} = 11.82 \text{ hr.}^{-1} = .197 \text{ min.}^{-1}$$

C. Comparisons

1. $\alpha = \dfrac{K_L a \text{ waste water}}{K_L a \text{ tap water}} = \dfrac{.197}{.474} = .417$

2. $\beta = \dfrac{C_s \text{ waste water}}{C_s \text{ tap water}} = \dfrac{8.74}{9.20} = .950$

TABLE 9

OXYGEN TRANSFER STUDIES
TEST #2

A. Determination of K_La of tap water
Temperature 18.3° C. O_2 Saturation 9.30 mg/1

Time (min.)	D.O. (mg/1)	C_s-C
0	.50	8.80
0.5	2.45	6.85
0.75	3.32	5.98
1.00	4.12	5.18
1.5	5.38	3.92
2.0	6.38	2.92
2.5	7.15	2.15
3.0	7.65	1.65
3.5	8.05	1.25

$K_La = 2.303 \times .242 = .565 \text{ min.}^{-1}$

B. Determination of K_La of waste water

Temperature - 18.3° C.

Dissolved Solids 932 mg/1

O_2 saturation (corrected for D.S.) 9.08 mg/1

Oxygen transfer

a. Equilibrium oxygen concentration 6.10 mg/1
b. Biological uptake rate 47.3 mg/1/hr.

Transfer coefficient

$K_La = r/C_s\text{-}C_e$

$K_La = 47.3/9.08 - 6.10 = 15.9 \text{ hr.}^{-1} - .265 \text{ min.}^{-1}$

C. Comparisons

1. $\alpha = \frac{K_La \text{ waste water}}{K_La \text{ tap water}} = \frac{.267}{.565} = .473$

2. $\beta = \frac{C_s \text{ waste water}}{C_s \text{ tap water}} = \frac{9.08}{9.30} = .976$

TABLE 10

OXYGEN TRANSFER STUDIES
TEST #3

A. Determination of K_La of tap water
Temperature 18.0° C. O_2 Saturation 9.42

Time (min.)	D.O. (mg/1)	C_s-C
0	1	8.42
0.25	2.05	7.37
0.50	3.00	6.42
0.75	3.90	5.52
1.00	4.68	4.74
1.50	5.90	3.52
2.00	6.80	2.62
2.50	7.40	2.02
3.0	7.95	1.47
3.5	8.30	1.12
4.0		.82

$K_La = 2.303 \times .254 = .592 \text{ min.}^{-1}$

B. Determination of K_La of waste water

Temperature - 18.0° C.

Dissolved Solids .220 mg/1

O_2 Saturation (corrected for D.S.) 9.05

Oxygen transfer

a. Equilibrium oxygen concentration 5.58 mg/1
b. Biological uptake rate 50.4 mg/1/hr.

Transfer coefficient

$K_La = r/C_s\text{-}C_e$

$K_La = 50.4/9.05 - 5.58 = 14.6 \text{ hr.}^{-1} = .243 \text{ min.}^{-1}$

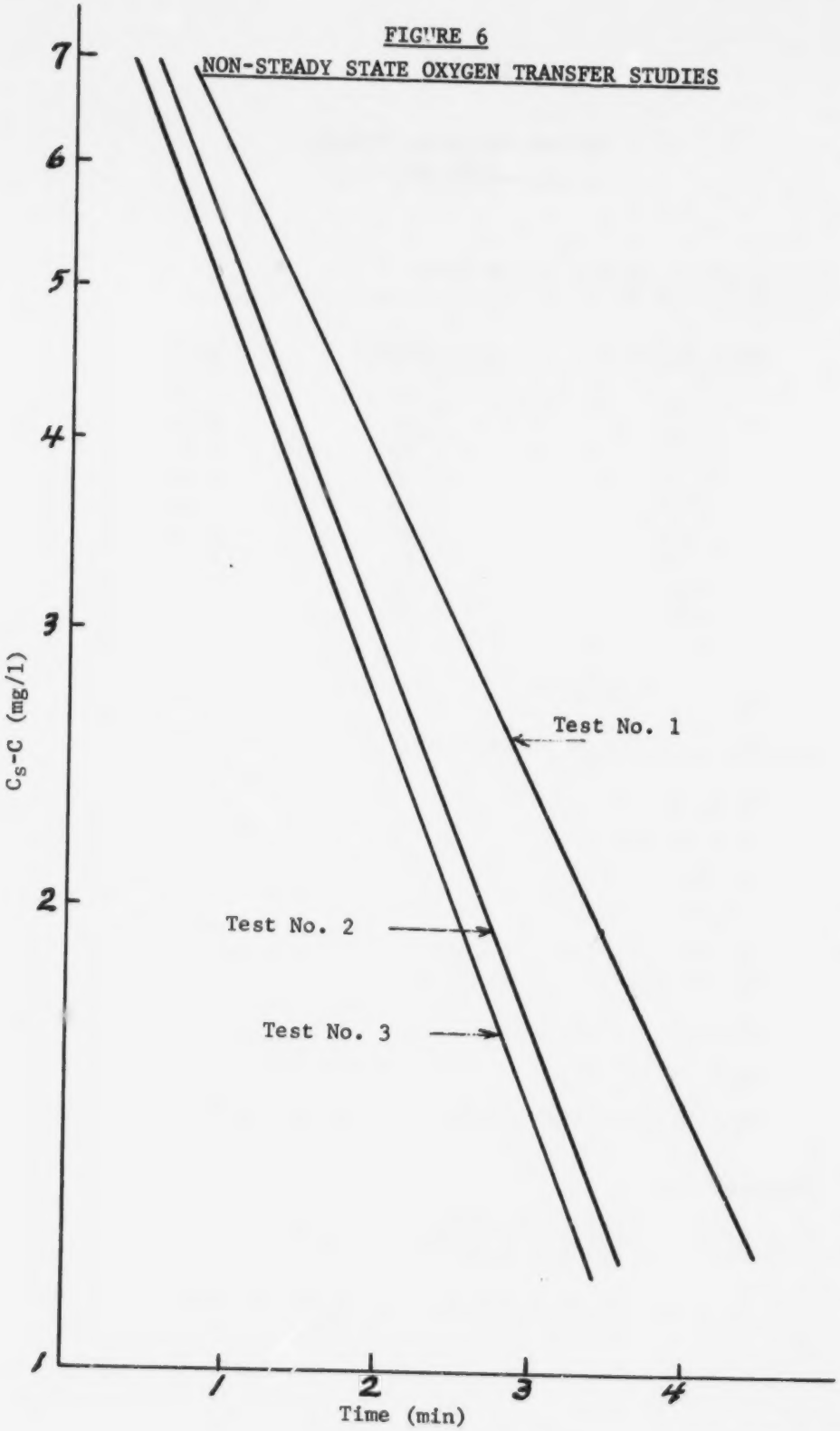
C. Comparisions

1. $\alpha = \frac{K_La \text{ waste water}}{K_La \text{ tap water}} = \frac{.243}{.592} = .412$

2. $\beta = \frac{C_s \text{ waste water}}{C_s \text{ tap water}} = \frac{9.05}{9.42} = .962$

FIGURE 6

NON-STEADY STATE OXYGEN TRANSFER STUDIES



SECTION IX

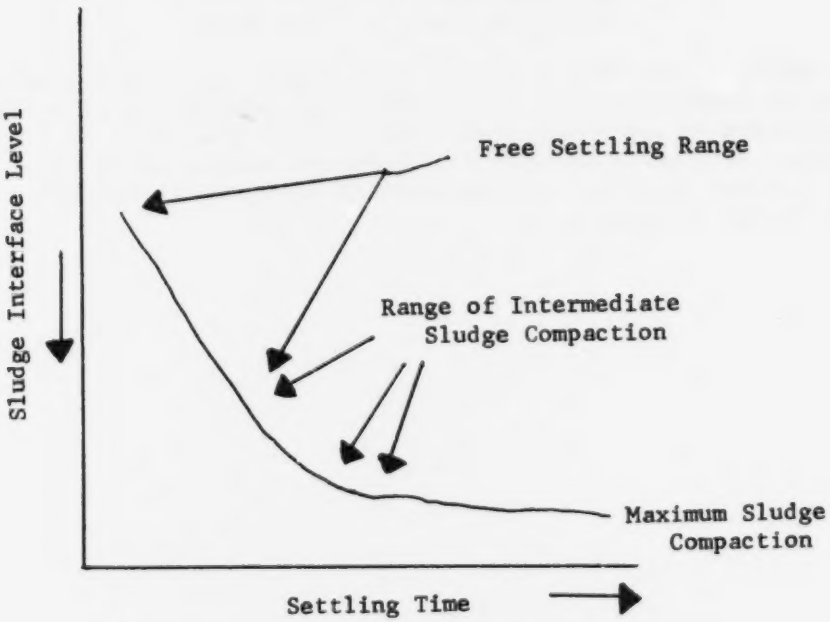
SLUDGE REMOVAL AND THICKENING

At this point it was apparent that a completely mixed activated sludge process would be utilized for achieving secondary treatment, thus, it was necessary to develop design parameters in order to size the necessary final clarification facilities and to size both chemical and biological sludge thickening tanks.

Laboratory settling studies were performed, similar to those described in Section V. A homogenous sample of the aeration basin effluent was placed in an 8 foot by 6 inch diameter settling column. Data was taken relating sludge interface level with settling time. A typical curve, as shown in Figure 7, can be developed from such data.

Figure 7

Sludge Thickening Curve



It is apparent from this curve that various degrees of sludge compaction can be achieved depending upon the settling time allowed. Design overflow rates can be calculated from various degrees of sludge compaction from the data developed in the settling studies.

Figure 8 shows a summary of the results of several individual settling studies performed on wastes of varied solids concentrations. From this figure a clarifier overflow rate can be determined for a specified MLSS level. Since these data were developed under ideal settling conditions, correction factors must be applied in order to compensate for the effects of turbulence, short circuiting, and inlet and outlet losses.

The secondary clarifier was designed such that the sludge would settle to an approximate 1 percent consistency. This resulted in a design overflow rate of 565 GPD/ft.^{2} and a design detention time of approximately 3 hours.

Design parameters for both the chemical and biological thickening tanks were developed in a similar manner. Chemical and biological sludge compaction levels were established at 8 percent and 2 percent consistency, respectively. The resultant design parameters were:

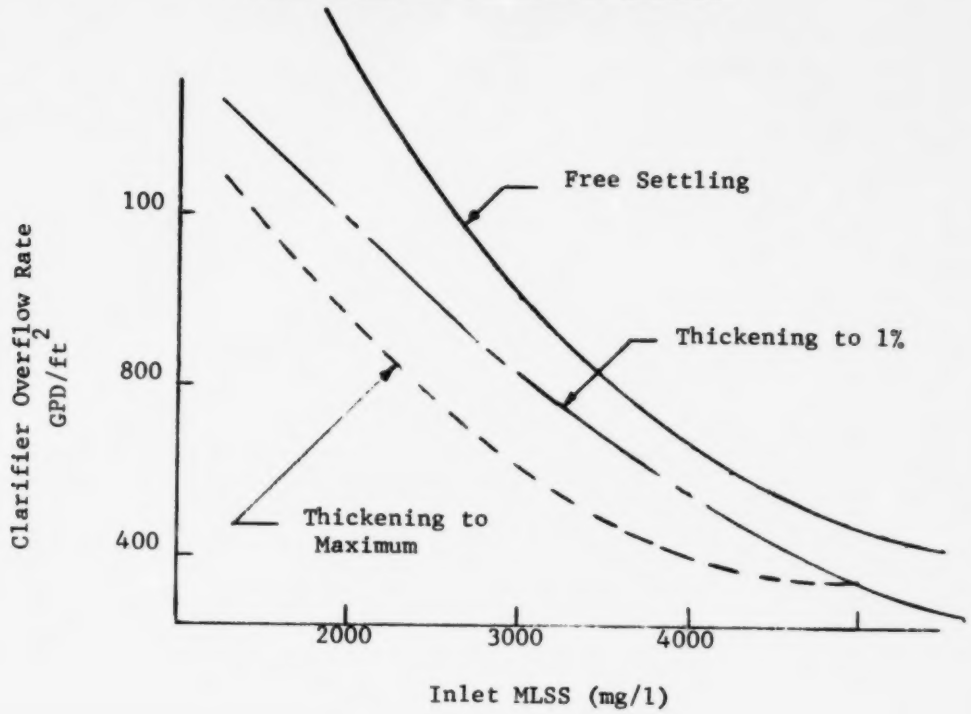
Chemical Sludge Thickener
- Overflow Rate = 160 GPD/ft.^{2}
- Detention Time = 11.3 Hours

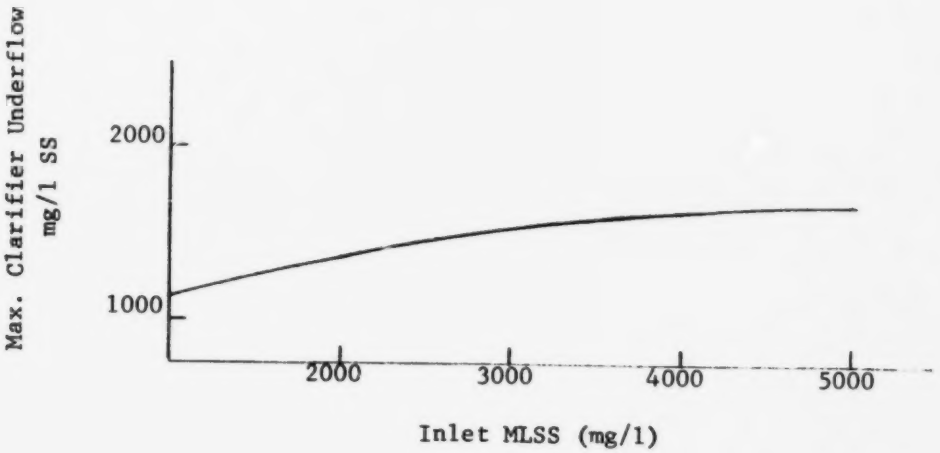
Biological Sludge Thickener
- Overflow Rate = 174 GPD/ft.^{2}
- Detention Time = 10.8 Hours

In addition to these studies, preliminary laboratory studies were performed in order to determine the feasibility of further sludge dewatering by centrifugation. The results from these preliminary studies were quite favorable. Equipment manufacturers were consulted for further details. Recommendations were made to install a centrifuge for sludge dewatering.

FIGURE 8

SLUDGE CLARIFICATION AND THICKENING





SECTION X

PROCESS DESIGN

The laboratory studies, as discussed in the previous sections of this report, provided basic design parameters for the Pedricktown Plant Waste Treatment System. Engineers of Roy Weston & Associates and the B.F. Goodrich Chemical Company developed the detail process design for such a system.

This section includes a summary of the resultant treatment system process design including a process flowsheet to facilitate understanding of the system. No attempt was made to include design calculations.

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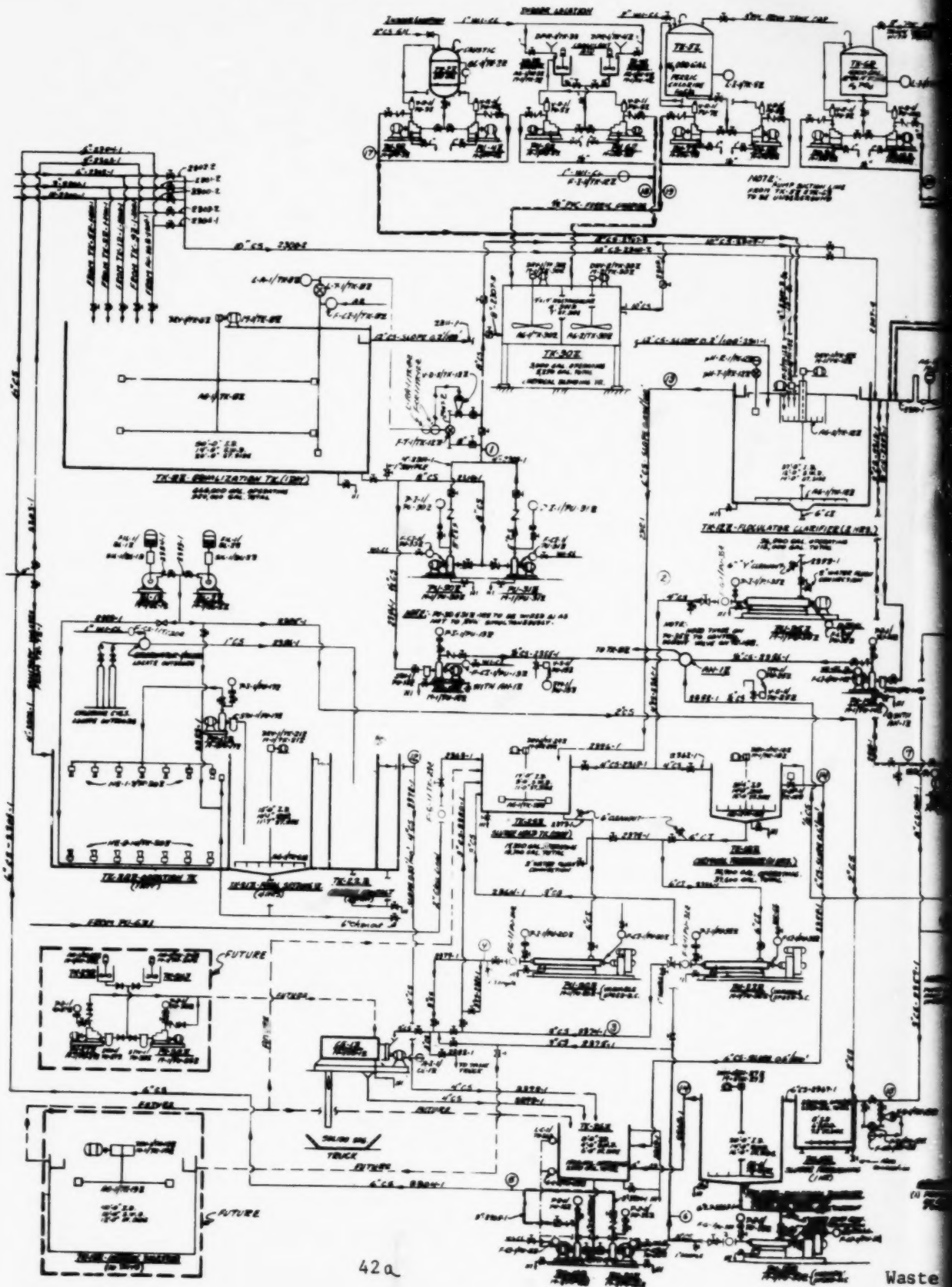

42a

Waste

42b

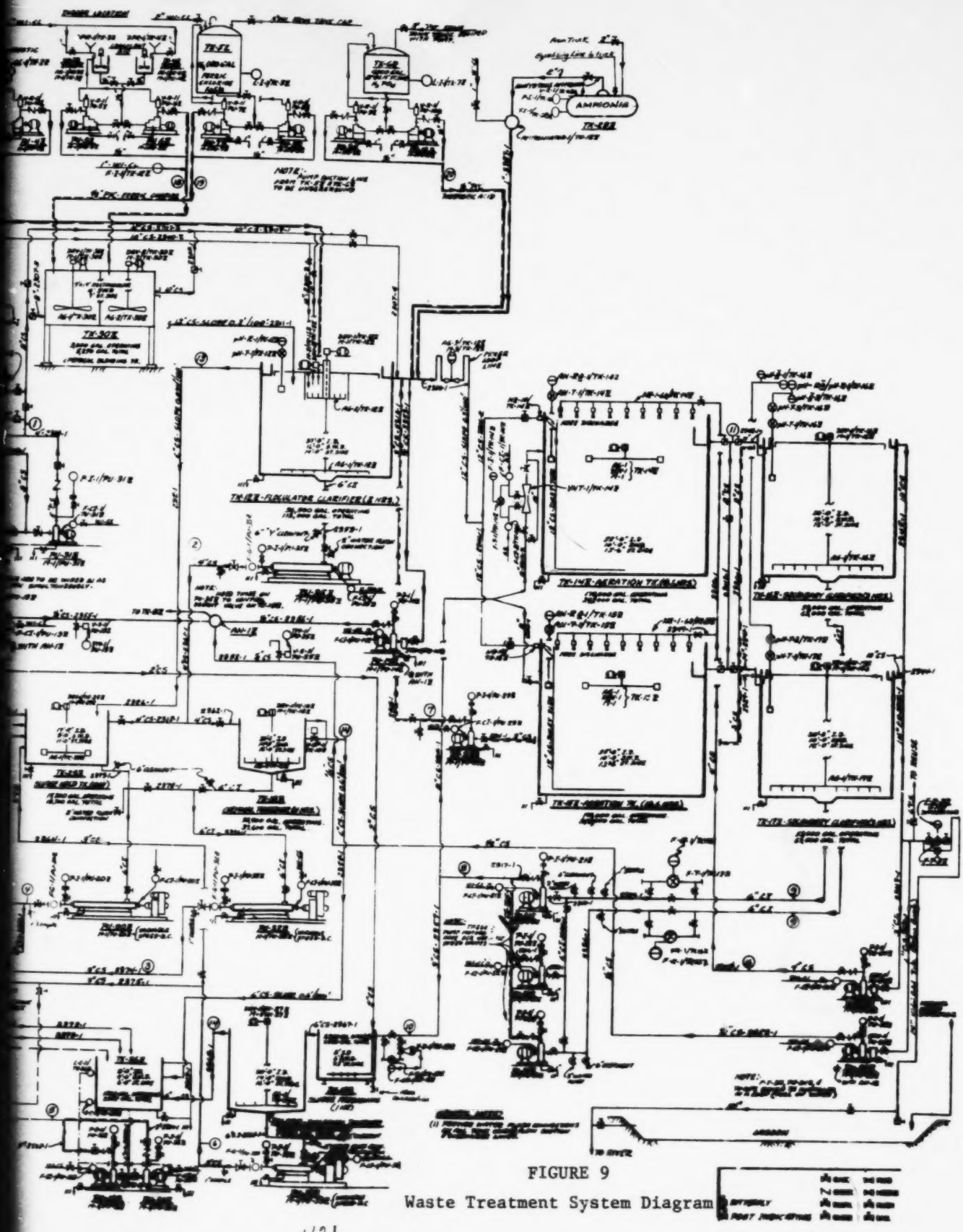

FIGURE 9

Waste Treatment System Diagram

Equalization Tank (TK-8Z)

This tank is sized at 950,000 gallons total to provide an equalization for both organic and hydraulic loads. The need for this facility was determined in part by the pilot plant studies and individual analysis of samples taken from an existing plant. The change in organic loading over a period of a day was great enough to justify this tank to prevent "shocking" a biological process following in the system. The following is a summary of the design of this tank:

Design Flow	-	0.8 MGD
Detention Time	-	1 day
Agitator	-	25 HP, 30 RPM, 95" in dia. turbine
Dimensions	-	90 ft. dia. by 20 ft. straight side
Construction	-	steel, above ground, baffled, pumped influent, pumped effluent.

Chemical Flash Mixing Tank (TK-30Z)

The purpose of this tank is to give approximately two minutes retention in each of two compartments, so that the coagulant and coagulant aid can be put into solution. Two tanks were provided in order to add coagulant and coagulant aids in the proper order. The agitation is quite vigorous to give good shear, as well as good blending. The following is a summary of the design of this tank:

Design Flow	-	0.8 MGD
Detention Time	-	4 minutes (total)
Agitator	-	2000 GPM pumping capacity
Dimensions	-	7 ft. by 14 ft. rectangular by 7 ft. straight side, 4 ft. SWD (Side Water Depth)
Construction	-	steel

Waste Water Transfer Pumps (PU-30 & 31Z)

These two pumps are sized to handle the design flow of 0.8 MGD individually. One pump will be used as a spare. Flow from these pumps is adjusted by a manual regulator. A magnetic flow meter adjusts a control valve to allow through the set flow desired.

Design Flow	-	600 GPM at 31' TDH
Construction	-	cast iron

Coagulant Aid Handling System (TK-3 & 4Z) - (PU-5 & 6Z)

The system consists of two 250 gallon tanks, each with agitators, to put the powdered coagulant aid into solution. The coagulant aid in the powder form is mixed with water through the use of an "Asperator"

Coagulant Aid Handling System (continued)

feeder. This feed mechanism wets the particle before it enters the 250-gallon tank. The coagulant aid solution is pumped by one of two (one is a spare) manually adjusted proportioning pumps to the flash mix tank.

Tank Construction	-	carbon steel
Tank Size	-	250 gallon
Pump Construction	-	steel
Pump Capacity	-	12.4 GPH

Ferric Chloride Handling System (TK-6Z) - (PU-9 & 10Z)

The ferric chloride tank is sized at approximately 15,000 gallon capacity. The tank was set at this capacity to insure enough space should railway tank cars be used to transport ferric chloride to the plant site in the future. The pumps to transfer the ferric chloride to the flash mix tank are proportioning pumps and are manually adjustable. One pump is a spare.

Tank Construction	-	fiberglass
Tank Size	-	12 ft. I.D., 18 ft. straight side
Pump Construction	-	PVC plastic
Pump Size	-	0 to 15 GPH

Flocculator - Clarifier (TK-12Z)

From the laboratory studies it was determined that part, or all, of the biologically inert solids were detrimental to the optimum performance of a biological system. In addition, it was also necessary to remove the inert solids for the following reasons:

(a) Minimize the difficulty in keeping the aeration tank contents in suspension.

(b) Maximize oxygen transfer.

(c) Reduce the quantity of biologically inert solids in the aeration tank and in the sludge aerobic digester which is planned for the future.

(d) Reduce the suspended solids and turbidity in the effluent.

Provisions are made at the flocculator-clarified to add caustic to insure pH control in the biological system. This provision was made

Flocculator - Clarifier (continued)

because of a "bulking" problem noted in the laboratory studies. The following is a summary of the flocculator-clarifier design basis:

Design Flow	-	0.8 MGD
Overflow Rate	-	1000 GPD/ft.^{2}
Flocculation Time	-	approximately 20 minutes
Construction	-	steel, above ground, pumped influent, gravity effluent
Accessories	-	mechanical skimmer and sludge collector, pH control

Phosphoric Acid Addition System (TK-6Z)

The phosphoric acid is provided to be added prior to the biological process. The phosphoric acid is needed as a nutrient in the biological system. The overall phosphorous requirement is 1 mg/l per every 100 mg/l BOD_5 entering the aeration basin. The amount of actual phosphorous added will depend on the amount already in the waste stream at that point.

A summary of the equipment and size of the tank is as follows:

Tank Construction	-	fiberglass
Tank Size	-	8 ft. I.D., 14 ft. straight side
Diaphragm Pump Construction	-	316 SS with Teflon diaphragm
Pump Capacity	-	1.8 GPH

Ammonia Addition System (TK-28Z)

Ammonia is supplied to the system prior to the aeration basin as a nutrient for biological growth. The ammonia supplies necessary nitrogen. The overall nitrogen needed in the system is 5mg/l per every 100 mg/l BOD_5 entering the aeration basin. The actual amount of nitrogen needed to be added depends on the amount already in the waste stream.

The ammonia is supplied to the system from a large storage tank through an Ammoniator. The ammonia leaves the storage tank as a gas and mixes with water in the Ammoniator, which forms ammonium hydroxide. This is fed to the waste stream prior to an in line mixer before entering the aeration basin.

Biological Aeration System (TK-14Z & 15Z)

After leaving the primary clarifier and blending with the nutrients, the waste flow passes through a flow splitter box that will insure an equal distribution of flow between the two aeration tanks. In the aeration basin the wastes will be mixed with an activated sludge for approximately 370 minutes. The activated sludge consists of bacteria

Biological Aeration System (continued)

and other micro-organisms within a biological floc. These organisms utilize the organic content of the waste water as food and decompose the organics to carbon dioxide and water. The oxygen needed is supplied by a fixed surface aerator. The aerator in each tank was sized based on the oxygen needed and the oxygen transfer characteristics of the waste water.

A provision has been made in both aeration basins to monitor dissolved oxygen and pH. These are both important since oxygen will be needed at all times to accomplish the organic decomposition, and a stable pH will be needed to prevent bulking.

Both aeration basins are equipped with spray nozzles to be used to break foam that may be caused by aeration. The treatment system effluent will be used for this service.

After leaving the aeration basin the waste water passes into a secondary clarifier. Here the biological solids are settled out, leaving a clear, low BOD_5 effluent. The settled solids are recirculated back to the aeration tank, or are wasted, depending on the requirements of the system. The design of the system from the laboratory work indicates that an MLSS level of 2500 mg/1 was optimum for that particular waste effluent at Pedricktown. To maintain the 2500 mg/1, recycle sludge at the concentration of approximately 6700 mg/1 will be recirculated at rates between 38.5 percent and 125 percent of the design flow. This capacity was provided in order to have the capability of handling larger MLSS levels in the aeration basin if it is desired in the future.

The aeration tanks are sized to handle 10-20 percent above the design flow without losing the efficiency as defined by the design. The following is a summary of the design figures:

Basin

Design Flow	-	0.8 MGD
Detention Time	-	370 minutes with 71.5% recycle 10.6 hrs. for the forward flow only
Volume	-	approximately 178,000 gals. each
MLSS	-	approximately 2800 mg/1 (90% VSS)
Est. Oxygen Uptake	-	70 mg/1/hr.
Design Temperature	-	13° C.
BOD_5 Removal Rate Coefficient	-	0.035 $min.^{-1}$ at 27° C. 0.015 $min.^{-1}$ at 13° C.
Dimensions	-	approximately 55 ft. diameter by 10 ft. SWD each
Construction	-	steel, above ground, baffled
Accessories	-	dissolved oxygen analyzers and recorders, froth sprays for foam control, pH control, nutrient addition

Biological Aeration System (continued)

Mechanical Aerators

Energy Oxygen

BOD_5 Removal	-	approximately 4560 lb./day at 27° C., 90% load
Oxygen Demand	-	0.916 O_2/lb. BOD_5 removed
Total Required	-	4,100 lb./day

Endogenous Oxygen

Oxygen Demand	-	1.42 lb. O_2/lb. VSS destroyed
Sludge Destruction	-	51 lb./VSS destroyed/100 lb. VSS under aeration at 20° C.
Total Required	-	875 lb./day at 27° C., 90% load

Oxygen Transfer Conditions

α	-	0.5
β	-	0.96
Design Temperature	-	13° C.
Motor HP Required	-	150 HP (at 85% overall energy transfer efficiency)
Aerators per Basin	-	75 HP - 2 speed

Secondary Biological Clarifiers (TK-16Z & 17Z)

The two secondary clarifiers are designed to operate at 53,000 gallon capacity with an overflow rate of 565 GPD/ft^2. The system was designed to have an overflow rate such that the sludge would settle to approximately a 1 percent consistency. The sludge recycle pumps are sized to return up to 230 percent of the design flow. The pumps are variable speed so that the full range, 0 to 230 percent, can be utilized without problems.

The whole biological system was of a flexible design so that the effluent from either aeration basin could be directed to either secondary clarifier.

Each secondary clarifier is equipped with a skimmer to remove any floating material that may accumulate on the surface of the clarifier. The following is a summary of the design:

Design Flow	-	0.8 MGD
Design Overflow Rate	-	565 GPD/ft^2
Volume	-	53,000 gallons each
Detention Time	-	190 minutes
Dimensions	-	approximately 30 ft. diameter by 10 ft. SWD
Construction	-	steel, above ground, gravity inflow at periphery, gravity takeoff at periphery
Accessories	-	mechanical skimmers and tow-brow sludge collectors

Biological Sludge Freshening Tank (TK-13Z)

The purpose of this tank is to reoxygenate the activated sludge wasted from the secondary clarifier. If the sludge was not reoxygenated an anaerobic condition might exist causing the release of methane gas, thus tending to float the sludge and making thickening difficult. The air to be supplied will come from the packaged air compressor provided with the sanitary waste treatment system.

The following is a summary of the design of this system:

Flow	-	43,800 GPD sludge
Detention Time	-	1 hour
Volume	-	2,000 gallons
Dimensions	-	7 ft. diameter by 6.5 ft. SWD
Air Required	-	80 SCFM
Construction	-	steel, above ground, pumped inflow from return sludge wastage, gravity overflow to sludge thickener

Biological Sludge Thickener (TK-27Z)

It is anticipated that the normal biological clarified sludge from the secondary clarifier will have a solids concentration between 0.5 and 1 percent. The thickener should concentrate the sludge to 2 percent. The thickening is accomplished by slowly agitating the sludge in the thickening tank causing it to settle into a more compact mass. The discharge from the underflow of the thickener can go directly to a centrifuge or a sludge blending tank to be centrifuged with chemical sludge from the primary clarifier. The supernatant liquid from the thickener passes back to the equalization tank.

The following is a summary of the biological thickener design:

Flow	-	43,800 GPD at 90% load
Overflow	-	29,200 GPD
Design Overflow Rate	-	174 GPD/ft^2
Detention Time	-	10.8 hours (liquid)
Volume	-	18,900 gallons (liquid)
Dimensions	-	20 ft. diameter by 14 ft. SWD
Underflow	-	14,600 GPD (2,420 lb. at 2% solids)
Construction	-	steel

Chemical Sludge Thickener (TK-18Z)

The purpose of this system is to thicken chemical sludge from the primary clarifier prior to centrifuging. The underflow from the primary clarifier will be approximately 2.5 percent solids concentration. It is expected that this will thicken to 8 percent solids. The thickening process

Chemical Sludge Thickener (continued)

is accomplished by slowly agitating the waste solids. The underflow from the chemical thickener is discharged to a sludge blending tank prior to centrifuging. The system is flexible so that the chemical sludge can be centrifuged separately, if necessary. The filtrate from the thickener is returned to the equalization tank.

The following is a summary of the chemical thickener design:

Flow	-	40,000 GPD
Overflow	-	28,500 GPD
Design Overflow Rate	-	160 GPD/ft^2
Detention Time	-	11.3 hours (liquid)
Volume	-	18,800 gallons (liquid)
Dimensions	-	20 ft. diameter by 14 ft. SWD
Underflow	-	12,500 GPD (9,280 lb. at 8% solids)
Construction	-	steel, above ground

Centrifuge (CE-1Z)

It is intended to use a solid bowl centrifuge for dewatering the waste sludge. The centrifuge is designed on a hydraulic basis to handle approximately 40,000 GPD of sludge.

Provision is made for adding a polyelectrolyte to the centrifuge to aid in the dewatering of the sludge.

The centrifuge filtrate will be returned to the equalization tank for further treatment.

The sludge cake (probably 15-25 percent solids) will be transported from the production plant property and disposed of at a suitable sanitary landfill site operated in accordance with the rules and regulations of the New Jersey State Department of Health. It is estimated that approximately 23 tons of solids per day will be disposed of in this manner.

Lagoon

The treatment plant effluent will flow through a "polishing" lagoon prior to discharge into the receiving stream. Some additional BOD and solids removal should be obtained.

This lagoon will also normally receive the storm water run-off from the operating area of the production plant. It is also anticipated that spills may occur in the plant despite the most careful precautions to prevent such incidents. This lagoon will be used to hold such spills, if the treatment system cannot handle them. It should be emphasized that such a provision is a safety factor and that spills are not anticipated to be a normal occurrence.

Lagoon (continued)

The lagoon will provide detention of the design industrial waste flow and a three-hour storm of one inch per hour that would have a frequency of greater than once in 10 years, according to the records of the U. S. Weather Bureau in Philadelphia.

The nominal dimensions of the lagoon are 200 feet by 250 feet with a dry weather operating depth of 2 feet and a storm operating depth of 4.25 feet.

Water Reuse

It is planned to reuse part of the water that will pass through the treatment system. Investigations are now underway to determine what additional treatment will be necessary to make the water acceptable for reuse.

Metering, Sampling and Monitoring

A total carbon analyzer will be used on-stream to analyze the influent to the treatment system, the effluent from the primary clarifier, and the effluent from the secondary clarifier. In addition, the waste water treatment operators will routinely sample and analyze the waste and solids at various locations throughout the system. The laboratory facilities provided in the treatment area will provide for a routine analysis of BOD, COD, TS, SS, VTS, VSS, pH, and SVI. Also, routine microscopic observations of the aeration tank mixed liquor will be made.

The treatment system has the facilities to meter the raw waste flow sludge returned to the aeration basin and sludge wasted to the thickening process. Other monitoring instruments are:

(1) pH control at the primary clarifier

(2) pH control at the aeration basins

(3) DO monitoring at the aeration basins

Continuous samplers have been provided on the raw waste stream and effluent to get a good composite each day, so that the laboratory tests mentioned above can be run.

SECTION XI

OPERATION

Overall performance of the wastewater treatment system has been superior, and to date, far exceeds design requirements. Hydraulic, organic, and solids loadings in the raw, untreated wastewater have not reached those design levels as given in Section 4. BOD_5 and solids removals have consistently averaged greater than 95 percent, with 95 to 99 percent removals not uncommon.

This section discusses the performance of the system and the design and mechanical problems encountered during system start-up and operation. Actual operating data of individual unit operations and unit processes is included.

For clarity of discussion, the system is divided into the following three phases of treatment.

Primary Treatment,
Secondary Treatment,
Solids Handling

Primary Treatment

Primary Treatment comprises wastewater equalization, chemical coagulation, solid flocculation and separation, pH control, and nutrient addition.

Pilot plant and laboratory studies indicated a need for good waste equalization prior to primary and secondary treatment. The equalization system provided (described previously) has performed satisfactorily in dampening fluctuations in pH, solids loading, organic loading, and hydraulic loading. The 950,000 gallon capacity system is operated at a two-thirds full level and is allowed to fluctuate about this level for hydraulic equalization. As a check on the blending and solids suspension effectiveness of the 25 HP 30 RPM agitator associated with this system, probing (or sounding) studies were conducted to determine if build-up of solid deposits were occurring. Investigation of the 90 foot diameter tank bottom particularly in those areas most remote from the agitation resulted in no solids build-up.

From the equalization tank, the wastewater is pumped on a controlled basis to a two-compartment rapid mix tank where ferric chloride, caustic, and coagulant aid are added. The wastewater flow is measured by a magnetic flow meter and controlled as a function of the liquid level in the equalization tank.

The flow measurement and control system have performed satisfactorily. Considerable problems have been experienced with the rapid mix tank sys-

Primary Treatment (continued)

tem. Initially, the ferric chloride was added at the bottom of the rapid mix tank below the 1.5 HP rapid mixer. Overall agitation and blending of the ferric chloride into the waste was adequate when related to detention time; however, localized areas of concentrated ferric chloride occurred in the rapid mix tank resulting in corrosion and failure of the tank bottom. This problem was corrected by relocating the ferric chloride addition to the top (water surface) of the rapid mix tank and by relocating a caustic neutralization addition to this same point. This method of caustic addition, although manual, has been adequate to maintain a satisfactory pH range.

Ferric chloride addition requirements have varied somewhat depending on solids loadings. Optimum dosage conditions are determined by periodic laboratory jar test procedures.

From the rapid mix tank, the wastewater gravity flows to the flocculator-clarifier. Tables 11 through 14 show actual operating data for a four-month period. Loadings and removals of suspended solids, COD, and BOD_5 are given for the primary treatment phase.

The suspended solids removal efficiency for the period was greater than 95 percent, resulting in a primary treatment effluent average concentration of 36 mg/l. Total solids removal for the period averaged 47 percent. COD and BOD_5 removals achieved in the primary system have been greater than anticipated from the laboratory and pilot plant studies. COD and BOD_5 removals of 64 and 85 percent, respectively, were observed for the reporting period.

These operating results were not achieved without problems. The flocculator-clarifier was designed so that the wastewater entered from above the tank rather than through the tank sidewall or bottom. The inlet piping terminated 18 inches directly above the flocculator compartment, allowing the wastewater to gravity drop to the compartment. This resulted in considerable turbulance and detriment to flocculation. To correct this problem, a cone was installed to deflect the influent water and reduce turbulance.

Problems were also experienced in removing floating solids. These problems were associated with the structural and mechanical design of the skimming mechanism and with the erection of the flocculator-clarifier tank shell.

The tank shell was erected without perfect alignment, thus resulting in a slightly out-of-round tank. Subsequently, the out-of-round tank resulted in scum flowing around the end of the skimmer arm at certain areas of the tank. The problem has been partially solved by adjustments to the wiper blades.

The skimming mechanism construction was of lightweight materials resulting in continuing maintenance attention for system operation.

Table 11
Flocculator-Clarifier Performance Data
Month 1

	Influent					Effluent				
Date	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l
1	196	196	1,503	162	765	31	20	1,125	128	109
2	140	132	1,144	67	800	22	17	1,068	93	171
3	732	444	1,263	35	804	25	14	965	14	113
4	1,140	920	1,471	75	720	33	26	989	20	68
5	548	420	1,222	134	931	41	19	979	71	156
6	604	528	1,473	114	856	40	35	921	34	262
7	868	624	1,580	140	823	20	10	951	63	269
8	370	280	940	115	621	15	7	1,031	66	145
9	310	270	758	44	307	13	11	1,048	12	121
10	320	250	1,160	164	564	18	10	1,079	66	124
11	780	590	1,718	228	706	16	8	989	124	392
12	542	508	1,344	173	771	20	13	927	127	210
13	506	460	1,422	193	624	-	-	1,817	112	382
14	944	706	1,725	220	940	29	5	880	140	268
15	420	360	1,137	148	660	8	2	786	104	143
16	314	268	1,053	51	454	3	0	967	65	100
17	488	386	1,340	273	818	11	2	866	99	138
18	744	562	1,684	140	778	-	150	915	39	215
19	814	676	1,944	183	1,160	11	6	939	104	180
20	512	438	1,518	272	784	38	12	1,023	130	108
21	748	688	1,582	255	1,063	48	40	908	91	291
22	244	208	1,050	157	348	33	20	1,010	61	202
23	328	252	929	108	328	22	7	945	77	105
24	272	240	1,054	147	519	39	23	931	77	115
25	756	604	1,627	94	838	3	3	1,074	33	62
26	1,688	1,376	2,520	107	1,147	15	13	1,134	51	76
27	1,412	1,204	2,152	114	965	18	10	1,029	23	74
28	1,412	1,180	1,853	99	1,370	18	18	1,100	10	82
29	1,112	632	1,892	29	532	20	20	1,064	16	83
30	1,664	1,372	2,010	16	1,192	75	44	1,163	-	67

Table 12
Flocculator-Clarifier Performance Data
Month 2

	Influent					Effluent				
Date	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l
1	1,530	1,130	1,894	119	1,247	26	19	1,032	22	69
2	870	830	2,005	49	1,408	45	34	1,029	17	115
3	908	816	1,724	295	1,237	36	25	891	52	171
4	800	672	1,572	131	930	45	25	945	38	140
5	732	664	1,493	173	827	16	11	900	49	154
6	450	380	1,241	111	568	9	7	829	17	107
7	750	660	1,323	60	704	19	15	888	11	15
8	920	800	2,141	170	1,874	15	10	907	17	77
9	928	832	2,136	141	1,108	39	37	921	42	93
10	1,400	1,360	2,430	82	1,284	31	20	850	55	126
11	998	836	2,124	254	1,157	33	27	891	110	234
12	240	190	2,022	282	1,802	49	40	979	184	336
13	1,126	1,000	1,824	224	1,705	26	18	866	99	222
14	808	694	1,537	90	827	34	26	823	24	91
15	1,002	600	5,333	199	1,685	20	4	931	31	97
16	2,444	2,212	3,308	283	2,399	12	6	881	70	81
17	1,556	1,372	2,756	264	2,570	31	51	887	68	224
18	840	720	2,187	232	1,990	40	96	815	70	170
19	1,212	1,136	1,859	134	1,411	46	13	826	65	181
20	1,220	1,112	1,788	90	1,243	33	25	750	50	126
21	988	964	1,601	154	1,126	27	26	836	17	87
22	510	470	1,520	176	-	25	23	814	12	-
23	2,180	2,080	3,048	205	2,427	59	56	787	5	92
24	1,990	1,950	2,791	174	1,754	30	27	900	13	83
25	1,530	1,480	2,044	129	1,483	72	46	804	7	71
26	1,296	1,228	2,008	72	1,631	52	44	763	4	114
27	1,220	1,064	1,788	34	1,601	162	147	839	2	122
28	1,088	1,088	1,733	83	922	320	220	921	13	109
29	860	796	1,723	108	1,106	18	13	989	13	168
30	1,556	1,444	2,145	213	1,200	24	13	973	39	282
31	3,270	3,050	4,368	293	1,191	73	70	927	99	490

Table 13
Flocculator-Clarifier Performance Data
Month 3

	Influent					Effluent				
Date	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l
1	2,520	2,410	3.307	388	2,047	58	57	1,032	56	428
2	1,490	1,370	2,539	142	460	2	1	1,021	41	460
3	1,440	1,220	2,646	217	955	20	9	990	74	193
4	1,280	980	2,366	168	620	35	33	1,127	31	225
5	1,000	610	2,122	205	1,115	20	13	995	59	295
6	1,730	1,370	2,637	329	1,842	112	76	830	67	480
7	1,970	1,830	2,995	319	3,312	123	91	1,087	109	261
8	-	-	2,860	268	1,772	-	-	1,105	98	288
9	1,600	1,330	2,770	368	1,492	33	6	1,089	137	271
10	1,930	1,550	2,373	286	1,069	77	47	938	109	237
11	1,600	1,590	2,488	267	1,614	25	25	896	105	226
12	1,310	1,290	2,551	200	1,709	22	19	887	93	191
13	1,070	810	1,982	137	947	29	8	809	56	135
14	1,090	950	2,236	345	2,039	44	53	916	80	142
15	990	1,010	1,946	283	1,980	93	87	899	81	193
16	1,020	1,000	2,150	131	1,768	32	29	897	90	187
17	850	840	1,859	-	1,161	14	13	941	87	100
18	180	180	1,011	260	673	80	54	920	60	82
19	136	88	916	390	1,019	21	12	744	65	136
20	376	280	1,215	275	699	21	8	830	50	92
21	248	192	1,040	293	1,650	55	47	846	69	194
22	768	532	1,587	322	3,102	36	20	958	127	176
23	716	444	1,684	211	1,670	34	23	950	86	153
24	472	208	1,600	113	1,258	21	12	871	23	93
25	260	220	1,011	75	762	28	14	803	15	48
26	332	272	1,425	79	767	20	10	934	7	141
27	700	616	1,539	304	1,541	20	14	949	80	95
28	2,012	1,936	2,905	134	1,134	38	38	971	87	163
29	1,665	1,605	2,722	184	3,363	18	18	917	81	140
30	1,000	960	2,286	346	1,383	35	22	988	204	339
31	600	540	1,526	198	1,080	37	27	929	158	305

Table 14
Flocculator-Clarifier Performance Data
Month 4

	Influent					Effluent				
Date	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l	SS mg/l	VSS mg/l	TS mg/l	BOD mg/l	COD mg/l
1	524	456	1,545	140	1,140	18	6	1,010	89	212
2	418	390	1,534	178	1,131	13	12	926	59	139
3	1,090	1,060	2,361	202	1,380	20	19	974	145	200
4	930	860	2,649	284	1,645	20	17	1,007	246	365
5	1,460	1,390	2,648	277	1,308	37	33	1,072	227	381
6	2,440	2,330	3,620	257	1,740	23	20	969	155	255
7	2,370	2,230	3,412	178	2,048	20	20	992	125	228
8	1,760	1,430	2,702	135	976	73	54	930	84	208
9	2,110	1,870	2,550	193	972	32	15	907	86	154
10	2,490	2,410	2,275	191	987	63	55	929	95	217
11	440	400	2,015	334	967	31	25	961	219	348
12	260	200	1,995	279	2,000	31	29	1,028	208	402
13	1,420	1,400	2,679	321	1,785	22	22	993	158	323
14	1,320	1,300	2,379	252	1,521	65	56	918	138	310
15	1,120	1,065	1,922	155	1,574	4	3	851	67	181
16	788	760	1,698	310	1,532	52	46	839	73	160
17	1,180	1,080	2,246	220	1,765	49	37	951	106	207
18	510	420	1,813	188	1,372	12	12	901	53	122
19	520	520	1,553	228	1,600	22	20	945	92	184
20	300	-	1,452	213	1,042	22	21	930	111	221
21	380	330	1,465	154	990	25	14	887	92	186
22	270	260	1,073	63	510	18	15	-	53	91
23	630	500	1,213	102	980	23	12	774	28	147
24	700	620	1,876	82	1,130	35	32	850	103	163
25	872	800	1,797	393	1,300	26	25	910	282	500
26	1,068	1,000	2,025	236	1,257	48	39	924	254	416
27	1,960	1,520	3,719	237	1,390	65	33	884	191	363
28	720	680	1,687	167	1,410	10	7	801	106	240

Secondary Treatment

Secondary treatment comprises biological oxidation via a completely mixed activated sludge process followed by clarification and sludge recycle.

Initial start-up of the biological system was quite smooth. When plant production operations started, the wastewaters were stored in the equalization tank until sufficient volumes were available to fill and supply feed to the biological aeration system. The aeration tank was filled with wastewater and aerators started. Activated sludge from two nearby municipal sewage treatment plants was introduced to the system as seed. Approximately 60,000 gallons were used. The activated sludge was added directly to the secondary clarifiers and fed immediately to the aeration system for oxygen via the sludge recycle system. The sludge added resulted in an aeration tank mixed liquor volatile solids concentration of 600 mg/l.

During initial start-up of production operations the wastewaters were extremely variable in volume and composition. Supplementary feed (corn sugar) was added to the biological system during this period.

To date, the organic loading to the wastewater treatment system has not reached design levels. This has resulted in the biological system being operated in the extended aeration range as can be seen from the data in Tables 15 through 18. These tables show calculated levels of the feed to microorganism ratio and the BOD removal rate as discussed in section VII. No meaningful correlations of this data with pilot plant conditions can be made while the system is operated in the extended aeration range.

The two-speed 75 HP aerators have been more than adequate to meet oxygen requirements. Only one train of the dual train secondary system was operated through the reporting period. One aerator on low speed has been used. Actual oxygen usage has been approximately 1.2 pound/pound of BOD removed. The average usage for Month 1 and Month 2 were 1.01 and 1.3 pound/pound of BOD removed, respectively. This compares favorably with conventional extended aeration systems.

The sludge return system and magnetic flow meters have performed quite satisfactorily but hydraulic problems on the discharge piping of the system have developed. The return sludge from both clarifiers is mixed in a common header and then the flow is split between the two aeration tanks. A side stream from this header allows sludge to be wasted to the sludge freshening tank. The return piping to the aeration tanks was sized large enough to allow maximum sludge flow back to one aeration tank in case one aerator was out of service. However, the large piping did not exert enough back pressure to allow sludge to be wasted under normal conditions unless the control valves were almost closed. This problem was corrected by inserting restricting orifices in the lines to the aeration tanks.

Secondary Treatment (continued)
Tables 19 through 22 show recycle sludge solids levels, secondary clarifier influent and effluent conditions, and effluent BOD_5 levels.

Sludge recycle concentration for the period averaged 5,160 mg/l suspended solids of approximately 82 percent volatile content. Secondary clarifier suspended solids removal averaged 99 percent resulting in an average effluent concentration of 20 mg/l and an overall suspended solids removal efficiency of 98 percent for the complete treatment system. The BOD removal for the complete treatment system exceeded 98 percent resulting in an average effluent concentration of 2.4 mg/l. Ammonia nitrogen and phosphate residuals average 0.65 mg/l and 0.29 mg/l respectively.

Solids Handling

The solids handling system was designed to handle two types of sludge; biological sludge and inert or chemical sludge. The chemical sludge is from two sources, the primary clarifier and the preclarifier in the process area. This sludge is composed primarily of PVC solids but also contains iron floc from the water treatment plant. The biological sludge is waste activated sludge from the secondary system.

The chemical sludge thickener has performed satifactorily. This tank was designed for both thickening and sludge storage. The only problems experienced with the thickener occurred when the sludge became so concentrated that the unit over-torqued. This usually happened when production was shut down and there was little flow through the system. The thickener can thicken up to 13 percent solids before problems occur.

The sludge concentration from the primary clarifier runs about 2 percent solids which compares with the 2.5 percent used for design. The sludge from the preclarifier is quite variable and may range from almost water up to about 25 percent solids. Normal operation is to thicken to approximately 8 percent solids. From the thickeners, the sludge is pumped to the sludge blend tank in order to insure a uniform feed to the centrifuge.

Throughout the brief period during which the biological sludge thickener was in service, performance was excellent. The sludge could be thickened to about 7 percent solids, which was greater than expected.

No problems were experienced with the centrifuge on initial start-up. Later a problem did develop with iron fines which were not being removed by the centrifuge. The centrate from the centrifuge was recycled to the head of the treatment system thereby allowing this iron floc to be removed again in the flocculator-clarifier. Subsequently, the fines continued to build up in the system. This necessitated the addition of a coagulant aid addition system which is shown on the flow sheet in Section X.

Typical operation of the centrifuge with a feed sludge of 8 percent solids resulted in a 25 to 30 percent solids cake and a centrate of .1 percent or less. Average daily wet sludge production was 16,716 pounds and 25,267 pounds for Month 1 and 3 respectively.

Table 15
Aeration Tank Performance Data
Month 1

Date	Temp. °C	Load L_1/S_1	Det.Time Min.	Rate Min-1	Loading #BOD/#VSS/Day	% Removed	Rate 20°C Min-1
1	19	.058	1281	.0617	.1331	99	.0655
2	19	.047	1364	.0265	.1040	97	.0281
3	19	.006	1203	.0224	.0143	96	.0238
4	17	.003	1195	.0326	.0064	97	.0391
5	16	.030	1267	.1113	.0708	99	.1415
6	16	.014	1050	.0314	.0361	97	.0399
7	17	.024	1413	.0439	.0533	98	.0526
8	16	.020	2000	.0655	.0388	99	.0833
9	16	.005	1568	.0045	.0095	87	.0057
10	18	.029	1167	.0180	.0684	95	.0203
11	19	.044	1152	.2144	.1088	100	.2277
12	20	.037	1116	.2267	.0926	100	.2267
13	18	.030	1123	.1986	.0754	100	.224
14	18	.033	1290	.1078	.0768	99	.1216
15	18	.021	1568	.1320	.0452	100	.1783
16	14	.016	1369	.0467	.0351	98	.067
17	14	.024	1089	.0445	.0609	98	.0638
18	15	.010	997	.0381	.0253	97	.0515
19	17	.026	1267	.0813	.0614	99	.0974
20	17	.033	1066	.0600	.0828	98	.0719
21	18	.020	1323	.0680	.0450	99	.0767
22	16	.012	2132	.0091	.0207	95	.0116
23	14	.015	1435	.0529	.0337	99	.0759
24	11	.015	2011	.0378	.0278	99	.0649
25	13	.005	2599	.0123	.0080	97	.01873
26	13	.009	2373	.0103	.0115	96	.0157
27	13	.006	2373	.0190	.0075	98	.0289
28	14	.002	2760	.0069	.0026	95	.0099
29	16	.004	2561	.0038	.0045	91	.0048

Table 16
Aeration Tank Performance Data
Month 2

Date	Temp. °C	Load Li/S_1	Det.Time Min.	Rate Min-1	Loading #BOD/#VSS/Day	% Removed	Rate 20°C Min-1
1	15	.004	1119	.0384	.0102	98	.0519
2	16	.004	1106	.0145	.0091	94	.0184
3	16	.012	1156	.0216	.0286	96	.0275
4	15	.009	1348	.0556	.0187	99	.0751
5	13	.004	1641	.0201	.0067	97	.0306
6	10	.003	2094	.0158	.0058	97	.0288
7	8	.002	2094	.0100	.0040	95	.0206
8	9	.005	1745	.0189	.0102	97	.0366
9	12	.012	1477	.0278	.0246	98	.0449
10	13	.016	1343	.0811	.0366	99	.1236
11	13	.030	1561	.4103	.0634	100	.2137
12	12	.048	1762	.2082	.0970	100	.3369
13	11	.024	1762	.1118	.0486	99	.1690
14	12	.005	1864	.0123	.0101	96	.0200
15	12	.009	1703	.0085	.0174	94	.0138
16	15	.022	1219	.0183	.0495	96	.0247
17	15	.030	904	.0139	.0785	93	.0188
18	15	.022	920	.0370	.0604	97	.0499
19	16	.018	1391	.0227	.0381	97	.0288

Table 17
Aeration Tank Performance Data
Month 3

Date	Temp. °C	Load Li/S_1	Det.Time Min.	Rate Min-1	Loading #BOD/#VSS/Day	% Removed	Rate 20°C Min-1
1	12	.018	1411	.0191	.0257	96	.0276
2	14	.017	1081	.0180	.0299	95	.0259
4	18	.013	663	.0141	.0381	90	.0159
5	20	.035	513	.0236	.1358	92	.0236
6	16	.031	653	.1011	.0918	99	.1286
7	16	.042	763	.0940	.1119	99	.1195
8	16	.040	757	.0310	.1065	96	.0395
9	17	.058	756	.1195	.1553	99	.1431
10	18	.031	779	.0687	.0806	98	.0775
11	21	.037	736	.0343	.1003	96	.0323
12	18	.044	744	.0195	.1200	94	.0220
13	12	.029	744	.0094	.0808	87	.0152
14	15	.049	650	.0121	.1502	89	.0164
15	17	.038	672	.0136	.1213	90	.0163
16	13	.038	699	.0115	.1237	89	.0174
17	15	.037	694	.0111	.1212	89	.0150
18	15	.034	695	.0093	.1090	87	.0126
19	14	.048	672	.0093	.1394	86	.0133
20	15	.071	695	.0066	.1699	82	.0089
21	17	.065	707	.0181	.1561	93	.0217
22	19	.088	769	.0813	.1998	98	.0863
23	21	.068	836	.0502	.1438	98	.0473
24	18	.026	842	.0097	.0624	89	.0110
25	19	.009	817	.0110	.0232	90	.0117
26	18	.007	654	.0038	.0175	71	.0042
27	12	.054	636	.0613	.1549	97	.0993
28	16	.046	542	.0624	.5102	97	.0794
30	18	.098	665	.1007	.2709	99	.1136
31	13	.053	1085	.0476	.1018	98	.0726

Table 18
Aeration Tank Performance Data
Month 4

Date	Temp. °C	Load Li/S_1	Det.Time Min.	Rate Min-1	Loading #BOD/#VSS/Day	% Removed	Rate 20°C Min-1
1	12	.020	1037	.0308	.0710	97	.0499
2	8	.013	827	.0218	.0501	95	.0449
3	13	.031	698	.0851	.1366	98	.1297
4	15	.075	806	.2022	.2325	99	.2732
5	17	.046	1095	.1286	.1208	99	.1541
6	18	.031	1135	.0674	.0784	99	.0760
7	17	.018	1091	.0247	.0451	96	.0296
8	18	.026	1105	.0557	.0682	98	.0628
9	15	.017	1064	.0260	.0451	97	.0351
10	14	.018	1049	.0292	.0485	97	.0420
11	16	.100	1059	.0508	.2174	98	.0646
12	18	.077	1044	.0488	.1359	98	.0551
13	21	.043	666	.1170	.1232	99	.1102
14	17	.028	875	.0778	.0740	99	.0931
15	17	.015	871	.0373	.0397	97	.0447
16	18	.020	893	.0806	.0526	99	.0884
17	19	.030	876	.0594	.0778	98	.0630
18	23	.019	855	.0608	.0507	98	.0507
19	23	.030	863	.1511	.0839	99	.1317
20	24	.035	1345	.1172	.0777	99	.0921
21	19	.039	1238	.0363	.0870	98	.0386
22	19	.024	1179	.0741	.0558	99	.0787
23	19	.015	709	.0150	.0459	91	.0160
24	15	.040	613	.0783	.1703	98	.1058

Table 19
Secondary Treatment Performance Data
Month 1

Date	Recycle Sludge SS mg/l	Recycle Sludge TS mg/l	Secondary Clarifier Influent SS mg/l	Secondary Clarifier Influent VSS mg/l	Secondary Clarifier Influent TS mg/l	Secondary Clarifier Effluent SS mg/l	Secondary Clarifier Effluent VSS mg/l	Secondary Clarifier Effluent TS mg/l	Effluent BOD mg/l
1	1216	2642	908	756	2091	14	6	997	1.3
2	2216	2828	1132	832	2077	15	12	1010	2.4
3	2356	3254	1612	1284	2126	6	6	976	.35
4	2630	3300	1670	1360	2087	14	14	945	.33
5	3180	3509	1520	1130	2140	18	18	945	.4
6	2410	3239	1310	1060	2143	5	5	928	1.2
7	3560	3912	1740	1210	2307	15	5	882	1.2
8	2430	3333	1480	1200	2380	9	5	954	0.5
9	2700	3035	1890	1700	2347	12	8	969	1.5
10	2870	3719	1610	1200	2517	15	2	1003	2.8
11	3810	4506	2050	1710	2924	8	4	966	0.6
12	4490	4608	2090	1750	2544	9	5	885	0.6
13	4960	5055	2110	1670	2708	7	4	891	0.7
14	5500	5296	2440	1840	2856	27	8	798	.8
15	4770	4566	2650	2110	2912	11	7	810	0.7
16	3980	4483	2400	2000	3039	7	2	851	1.0
17	4890	4451	2610	2120	2682	8	3	802	2.0
18	4640	5032	3050	2350	2680	13	9	800	1.0
19	5050	5423	2610	1920	3112	16	1	816	0.7
20	5240	5356	2950	2180	3274	16	4	877	2.0
21	5620	6045	2920	2080	3428	27	22	892	1.0
22	5160	5764	2680	1770	3511	13	12	885	3.0
23	3940	4546	2850	2270	3575	20	7	898	1.0
24	-	-	2540	1920	3468	23	15	881	1.0
25	3840	4707	2890	2310	3749	10	5	924	1.0
26	3040	3912	3350	3744	4128	16	6	982	2.0
27	1410	2077	3180	2510	3992	16	14	1021	.35
28	1660	2338	3470	2840	3801	10	10	1010	.18
29	-	7100	3500	2810	3813	-	-	-	1.3
30	1940	2181	4010	3230	4071	34	23	1051	-

Table 20
Secondary Treatment Performance Data
Month 2

Date	Recycle Sludge SS mg/l	Recycle Sludge TS mg/l	Secondary Clarifier Influent SS mg/l	Secondary Clarifier Influent VSS mg/l	Secondary Clarifier Influent TS mg/l	Secondary Clarifier Effluent SS mg/l	Secondary Clarifier Effluent VSS mg/l	Secondary Clarifier Effluent TS mg/l	Effluent BOD mg/l
1	4570	4820	3640	3080	3871	12	9	1086	0.3
2	6420	6378	2700	2190	3475	27	8	986	1.0
3	5560	6630	2680	2190	3206	23	23	919	1.8
4	5870	6566	2510	2010	3123	109	10	881	0.6
5	5730	5932	2390	2170	2993	16	6	904	0.2
6	4200	5275.	2010	1840	2762	5	4	828	0.7
7	5000	5335	1920	1750	2635	16	7	830	0.5
8	-	-	1820	1330	2500	9	6	869	0.2
9	4240	4732	1920	1650	2574	10	4	842	1.0
10	3600	4269	1940	1620	2652	18	13	843	0.4
11	3540	4273	1590	1440	2703	8	6	837	0.5
12	3460	3929	1900	1690	2734	14	9	825	0.4
13	3540	4039	2300	1790	3779	15	9	851	0.8
14	3360	3706	2100	1850	2362	13	8	823	2.0
15	3280	3854	1980	1470	2763	19	4	827	2.0
16	3520	4120	1840	1690	2685	11	9	835	3.0
17	4800	4164	1180	1140	2220	20	11	826	5.0
18	3980	4284	1960	1790	2649	11	5	750	2.0
19	980	2596	2850	2250	3273	42	19	745	2.0
20	468	1133	3310	2760	3835	-	-	-	1.0
21	704	1369	2890	2530	3546	10	8	694	1.0
22	5250	5977	3000	2630	3597	11	10	797	1.0
23	4870	5596	2810	2390	3424	5	5	780	2.0
24	5310	6372	2580	2240	3176	9	8	766	1.0
25	3960	4798	2230	1840	3047	7	1	775	0.2
26	3510	4213	2660	2240	3301	21	12	774	0.9
27	3140	3765	2710	2290	3167	0	0	746	-
28	2840	4176	2530	2180	3040	48	36	733	0.9
29	3810	4560	2300	1950	3203	22	17	770	1.1
30	4680	5515	1390	1160	3252	37	26	767	0.5
31	7770	8591	2580	2310	3326	7	12	820	2.2

Table 21
Secondary Treatment Performance Data
Month 3

Date	Recycle Sludge SS mg/l	Recycle Sludge TS mg/l	Secondary Clarifier Influent SS mg/l	Secondary Clarifier Influent VSS mg/l	Secondary Clarifier Influent TS mg/l	Secondary Clarifier Effluent SS mg/l	Secondary Clarifier Effluent VSS mg/l	Secondary Clarifier Effluent TS mg/l	Effluent BOD mg/l
1	9780	10,284	2470	2220	3206	20	23	865	1.8
2	11,880	12,290	2060	1830	3088	5	3	392	1.9
3	8430	8812	2260	1860	3099	20	11	1011	2.6
4	11,280	11,517	1970	1770	2831	28	27	1012	3.1
5	9330	9122	1470	1220	2613	18	14	997	4.5
6	5650	5040	2090	1610	2680	32	4	601	1.2
7	5720	6715	2180	1840	2707	29	23	938	1.3
8	-	7200	-	-	2853	-	-	1034	4.0
9	8110	8930	2380	1680	3024	3	0	971	1.6
10	7380	6320	2250	2500	3377	56	28	930	2.0
11	6150	6742	2170	2050	2920	13	13	904	4.0
12	7600	7862	1660	1500	2662	24	18	942	6.0
13	4600	5107	1670	1340	2601	41	14	869	7.0
14	2740	3800	1250	1180	2206	60	30	898	9.0
15	4180	5348	1530	1430	2261	20	2	839	8
16	4450	5055	1750	1500	2342	44	40	894	10
17	3280	3989	1520	1490	2311	54	42	892	10
18	3370	4097	1450	1140	2221	41	40	866	8
19	2930	3580	1480	1000	2136	64	40	824	9
20	7640	8056	1500	610	2122	26	16	778	9
21	9020	10,323	1420	900	1880	8	6	783	5
22	8280	8613	1810	1190	2274	35	28	800	2
23	6500	8160	1440	1030	2384	23	15	906	2.1
24	4430	5350	1610	630	2436	11	8	924	2.7
25	5300	6118	1490	1140	2294	20	10	765	1.6
26	5600	6590	1620	880	2308	15	9	883	2.2
27	4840	6271	1630	1170	2433	20	14	891	1.9
28	6560	7250	1710	1540	2601	20	20	941	2.4
29	10,010	10,657	1910	1720	2772	5	5	870	3.0
30	10,760	11,985	1880	1630	2801	17	11	902	3.2
31	7450	8075	2390	2060	3111	19	10	826	3.2

Table 22
Secondary Treatment Performance Data
Month 4

	Recycle Sludge		Secondary Clarifier Influent			Secondary Clarifier Effluent			Effluent
Date	SS mg/1	TS mg/1	SS mg/1	VSS mg/1	TS mg/1	SS mg/1	VSS mg/1	TS mg/1	BOD mg/1
1	7010	7745	2060	1740	3215	14	4	873	2.7
2	3810	3280	2320	2050	3182	22	19	937	3.1
3	4400	5015	2480	2190	3208	40	39	934	2.4
4	6100	7177	2300	1890	3465	16	15	911	1.5
5	6790	7593	2770	2470	3720	12	10	921	1.6
6	6590	7340	2810	2510	3741	5	2	956	2
7	6690	7633	2620	2390	3846	5	0	973	2
8	7320	8034	2480	2460	3670	23	5	890	3
9	7270	7777	3020	2580	3531	20	9	825	3
10	7070	8006	2760	2690	3767	16	11	816	3
11	8040	8788	1660	1370	2821	13	2	851	4
12	14,890	16,076	2180	2110	3563	20	12	919	4
13	10,240	11,304	3100	2770	4151	5	5	896	2
14	11,730	12,298	3390	3070	4090	27	26	887	2
15	9880	11,969	3140	2790	-	17	17	862	2
16	10,570	-	2550	2240	-	41	39	960	1
17	9040	-	2590	2240	-	39	30	857	2
18	8230	-	1980	1760	-	19	18	908	1
19	6040	-	2030	1830	-	15	14	839	0.7
20	5710	-	1630	1530	-	16	16	880	0.7
21	3070	-	1460	1230	-	12	3	871	2
22	3030	-	1340	1160	2566	13	12	875	0.6
23	5670	-	1440	1240	-	10	4	825	2.4
24	9090	-	1690	1420	-	20	18	751	7.1
25	7710	-	2300	2070	-	30	14	854	9.0
26	8630	-	2580	2290	-	26	20	819	9.2
27	8770	-	3000	2460	-	56	26	826	4.2
28	8850	-	2760	2590	-	3	2	763	4.9

SECTION XII

WASTEWATER RECYCLE AND REUSE

The preservation of our natural resources through recycle and reuse processes is becoming evermore common throughout industry today. Although recycle and multiple reuse of cooling waters has long been practiced, only during the past few years has such attention been given to the recycle and reuse of wastewater streams.

Recycle and reuse of the secondary treated PVC production plant wastewaters from the Pedricktown plant has been evaluated. The planned recycle system including actual pilot operation data is presented and discussed in this section.

The raw water supply for the plant is from underground wells. Water is pumped from two separate underground aquifiers and treated according to its ultimate use. Two separate but identical raw water treatment systems were installed with the original plant. One of these systems has been utilized for evaluation of wastewater recycle.

The quality of the secondary treated wastewater has been high, as can be seen from Tables 19 through 22 of Section XI. For the past several months a recycle evaluation program has been underway in which 100 gallons per minute of secondary treated effluent has been recycled to the raw well water treatment system for further treatment. Tables 23 and 24 show typical water quality after treatment in the well water system. This water is of acceptable quality for reuse as service and cooling water.

To date recycle has been accomplished through a temporary system of pumps and firehoses. Plans are now underway to install a permanent recycle system for further evaluation of wastewater recycle and reuse.

The secondary treated effluent will gravity flow to a 1,500 gallon surge tank in which chlorine is added for bacteria control. From the surge tank the chlorinated wastewater will be pumped to the existing water treatment system. The existing water treatment system, supplied by Los Angeles Water Treatment Company, consists of an aeration tower, followed by a reaction-precipitation-sedimentation tank, followed by an anthracite coal filter. From the water treatment system, the treated waters will gravity flow to the treated water reservoir. These waters will then be used for cooling purposes, service water, and fire water.

Table 23
Recycle Water Quality

COD mg/l	pH	Iron mg/l	Residual Chlorine mg/l	Turbidity JTU	Dissolved Solids mg/l
79	8.0	.25	.01	4	1,050
89	8.15	.55	.01	11	-
98	7.8	.35	.03	10	1,200
98	8.25	.28	Nil	8	1,200
54	8.5	.42	.01	25	1,350
121	7.8	.63	Nil	20	1,300
90	7.65	.35	Nil	25	1,350
60	7.45	.1	.05	10	1,300
203	8.0	.9	.03	25	1,150
106	8.25	.23	.03	48	1,100
70	8.3	.45	.15	30	1,200
145	8.0	.14	.04	40	950
157	7.8	.1	.05	10	-
104	8.15	0.4	.06	21	1,120
70	8.05	.47	.01	35	1,125
79	7.35	0.48	.02	25	990
100	7.95	0.95	.07	43	970
110	7.95	1.2	0.10	43	1,030
114	8.1	0.06	0.12	38	1,100
74	7.55	0.76	0.11	26	1,090
101	8.2	0.94	0.08	26	1,120
93	7.25	0.60	1.1	36	1,110
85	7.5	.04	1.38	37	1,290
99	7.6	.15	.14	24	1,370
80	8.1	.20	.08	13	1,400
44	7.8	0.45	0.01	0	880
37	7.15	0.32	0.01	1	860
22	7.8	.02	<.01	4	850
33	7.81	.04	<.01	11	820
27	7.7	.05	<.01	16	800

Table 24
Recycle Water Quality

COD mg/l	pH	Iron mg/l	Residual Chlorine mg/l	Turbidity JTU	Dissolved Solids mg/l
125	7.5	.05	.05	28	910
83	8.0	.05	<.01	12	1,000
55	8.02	.031	.02	21	990
74	7.6	.02	.01	20	930
57	8.1	.70	-	19	910
75	7.8	.05	.07	18	990
79	8.0	.4	.05	25	900
129	8.1	.02	<.0	20	950
106	8.0	.8	.03	25	900
225	8.2	.3	<.01	25	1,000
119	8.4	.023	<.01	10	1,200
-	7.2	.05	.09	11	850
104	8.15	.4	.06	21	1,120
19	7.4	.03	.15	0	900
35	8.1	.04	.04	5	900
-	7.3	.03	.01	3	1,000
38	7.2	.05	.25	0	950
43	7.4	.01	.02	0	1,000
37	7.5	.03	.01	0	900
24	8.1	.01	.01	0	1,000
34	8.25	.05	.01	9	1,050
19	8.15	.05	.01	0	1,000
21	8.1	.03	.01	0	1,000
25	8.25	.05	.05	5	1,025
34	8.1	.05	-	3	1,000
-	8.05	.32	.01	11	880
26	7.4	.03	.01	10	970
-	7.5	.10	.01	12	900
25	7.5	.18	.02	0	905
42	7.7	.34	.01	0	875

SECTION XIII

ABBREVIATIONS

PVC	Poly vinyl chloride
BOD	Biochemical Oxygen Demand
BOD_5	Five-day biochemical oxygen demand
C	Temperature - degrees centigrade
COD	Chemical Oxygen Demand
TC	Total Carbon
TS	Total Solids
VTS	Volatile Total Solids
SS	Suspended Solids
VSS	Volatile Suspended Solids
JTU	Jackson Turbidity Units
RPM	Revolutions Per Minute
mg/l	milligrams per liter
PSIG	Pressure - pounds per square in guage
GPD/ft^2	Gallons per day per square foot
DO	Dissolved oxygen
ml	milliliters
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
SVI	Sludge Volume Index
MGD	million gallons per day
GPM	gallons per minute
hr	hour
SWD	side water depth
TDH	total dynamic head
dia	diameter
HP	horsepower
I.D.	Inside Diameter
SCFM	Standard Cubic Feet per Minute
lbs	pounds
%	percent

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SECTION XIV

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27 Abstract B. F. Goodrich Chemical Company has completed construction and has begun operation of a new polyvinyl chloride (PVC) production plant that includes emulsion, suspension, and bulk polymerization processes. The wastewater treatment system for this plant was designed to meet the stringent discharge requirements of both the State of New Jersey and the Delaware River Basin Commission. The wastewater treatment system consists of a primary-secondary completely mixed activated sludge process including equalization, flocculation, clarification, mechanical aeration, nutrient addition, sludge thickening and centrifugation, and automatic process monitoring. Although the Company operates several PVC production plants in the United States, none of these plants could be considered to be a duplicate of the proposed production plant. Therefore, it was necessary to simulate the anticipated production plant wastes by selective sampling and to conduct pilot plant treatment studies. This report presents summarized results of the laboratory and pilot plant studies and a complete and detailed description of the full-scale wastewater treatment system as constructed. Actual operating data of the system is included and supplemented by discussion of individual unit operations and unit process performance. Evaluation of a full-scale wastewater recycle and reuse system is included. This report was submitted in fulfillment of Project Number 12020 DJI under the sponsorship of the Office of Office of Research and Monitoring, Environmental Protection Agency.

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